Where the Macadam Ends and the Dirt Begins, Kenosha, Wis.

WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY.

E. A. BIRGE, Ph. D. Sc.D. Director.

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HIGHWAY CONSTRUCTION

IN

WISCONSIN.

BY

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PREFACE.

For several years there has been a demand in Wisconsin for information concerning the manner in which the different street pavements have been constructed, and for fuller information concerning the materials which are available for street construction. It was mainly on account of this call for information on street construction that the preparation of this monograph was undertaken. The information contained herein is intended primarily for those interested in the construction and maintenance of streets in cities, towns and villages in Wisconsin, although a great part of the report is equally applicable, in the principles of street construction and maintenance, to rural districts. An attempt has been made to discuss impartially the different pavements, hoping to furnish unbiased and reliable information as to their merits.

The data used in this report have been collected during a period of several years. Nearly all of the quarries from which stone is taken for purposes of road construction have been examined personally by the author. Having a knowledge of the age of the different pavements in the cities and towns, and knowing the manner of construction and the traffic to which the streets have been subjected, the author has inspected in person nearly all of the pavements in the state. The data as to year of construction, cost of maintenance, cost of construction, etc., were obtained either from the city engineer or the city clerk of the different municipalities. For some of the cities the information is not as complete as was desired. This is due, in most cases, to the incomplete manner in which the records have been kept, no attempt having been made to preserve in accessible form data relative to the methods of street construction and maintenance.

This report is of a preliminary nature and was brought out more for the purpose of bringing before the public the facts relating to the present condition of Wisconsin pavements and to stimulate an interest in highway construction, than to provide the detailed information concerning local conditions, road metals, subsoils, grades and drainage, which is needed to bring about the necessary improvements.

Conditions in each county should be studied in detail and the information gathered should be compiled and published in such form as to be of service to the supervisor of each road district.

There is no department at present so well equipped to begin this work as the State Geological Survey. However, there will come a time,—not far distant,—when Wisconsin must have a Highway Commission appointed for the purpose of laying out and constructing state highways, after the plan of the Massachusetts Highway Commission. Until such time, the investigation of the conditions and materials should be carried on in a vigorous manner by the Geological Survey.

The illustrations used in this volume have nearly all been collected in Wisconsin. Most of the cross-sections of pavements and other drawings have been copied from blue prints of drawings actually used in the construction of pavements in Wisconsin cities and furnished to the author by the different city engineers. Very few ideal drawings of pavements have been used. For the ideas embodied in any of the drawings used in this report the author makes no claim. Lack of time has prevented the preparation and publication of a bibliography.

For co-operation in the collection and collaboration of the information contained in this deport, I am very greatly indebted to the city engineers, city clerks and mayors of the various municipalities in the state. Without their hearty co-operation this report could never have been made possible. Among those who were especially active in furnishing data, drawings and maps may be mentioned, P. P. Chadek, Antigo; W. G. Kirchoffer, C. E., Baraboo; Dr. A. C. Mailer, De Pere; L. W. Wolf, C. E., Eau Claire; A. E. Badger and C. V. Kerch, C. E.,

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INTRODUCTION.

The purchaser or seller who is separated from the railroad station by ten miles of paved roads, is actually nearer the market than the person who is separated by five miles of unimproved roads. Good roads mean heavier loads, more rapid transit and a longer life for vehicles and horses.

The introduction of the telephone and rural free mail delivery, has brought the producer and consumer much closer together and ought eventually to assist in better maintaining an equilibrium between supply and demand. However, as long as the highways remain unimproved, the telephone and rural free mail delivery can only have their full value during good weather. Heavy roads, deep with sand or mud, permit the carrying of only partial loads, while the injuries sustained by vehicles and horses on rough roads frequently eliminate a large portion of the profit which would otherwise result from a rise in the market price of farm produce.

It is said that in many of the European countries a dog is often able to draw a load to market which a horse cannot draw in the United States. The Carthaginians living on the northern coast of "Darkest Africa," first inaugurated the public road as a necessity of commerce. The Roman roads had for their object the quick movement of troops. However, they were built in such a substantial and permanent manner that they have outlived the empire itself and have now become routes of commerce.

James D. Reid, commercial agent at Dunfermline, Scotland, in 1891, said in a special consular report on "Streets and Highways", "Roads are the life and necessity of all Scottish indus-

tries and their value increases rather than diminishes with railroad extension. Property would without them be comparatively valueless."

The bicycle has had a decided influence in hastening the improvement of the highways; but owing to the fact that it is not adapted to the carrying of produce, it has been unable to exert sufficient influence to bring about the changes so much needed by the business and commercial public. The automobile, on the other hand, may eventually become of sufficient importance, as a commercial factor, to demand the permanent improvement of the highways. There may come a time when the steel rail will be discarded in interurban and rural transportation, and be replaced by a smooth pavement. There may come a time when state and even trans-continental highways will be built of smooth, permanent pavements over which the automobile can travel with the same speed that the interurban car travels today.

Up to the present time, highways in Wisconsin have meant simply narrow tracks of land connecting different parts of the country. The highest conception of the public thoroughfare in many parts of the state has been its maintenance in a passable condition. Any economy which might be involved in the construction of permanent pavements has been given very little attention by the people, and much less by the state legislature. Up to within a few years ago, little or no attempt had been made to educate the people in the principles of road construction and maintenance. In the country districts the improvement of the highways has been mainly in charge of persons who have had little or no knowledge of road construction. The one idea in road construction, as exemplified by the work of the roadmaster, has been to fill the gullies and level off the roadway with such material as might be closest at hand. The iniquitous system of "working out" the road tax still exists in most parts of the state. Under this law the services which are given, in lieu of taxation, are usually far from commensurate with the needs of the public. A new system must be substituted for this before we can expect to better the condition of the rural highways.

The problem of highway construction and maintenance differs somewhat between the country and city, although they are closely allied. The difference is only one of degree. The concentration of traffic on the business streets in the cities necessitates, as a rule, the construction of a more durable pavement than is demanded by the light traffic of the rural highways. The greater valuation which is attached to city property, makes the burden of constructing the more costly pavement less proportionately, than it would be to construct a less expensive pavement in the country.

The cities, towns and villages, however, are the places to which the people of the country must look for practical demonstrations in the science of road construction. Most Wisconsin cities employ competent engineers to superintend the construction of the pavements; and one may find in these cities as a whole nearly every important class of pavement. The Wisconsin municipalities are improving their streets so rapidly that the list of street pavements given in this report will be very incomplete when it comes from the press. The improvement of the city and town streets naturally precedes that of the country highways and it may be some years before the country roads are to any extent permanently improved.

The following chapters of this report contain discussions of the various materials now used in the constructions of pavements; of the methods of constructing the different pavements, and of the experience of the different Wisconsin cities in the use of these pavements. The subject matter of Chapter V, which is a discussion of the pavements in Wisconsin cities, has been arranged according to counties, alphabetically. Under each county, besides a discussion of the city street pavements, there is a short description of the soils, surface configuration and road metals. There is necessarily much repetition in this chapter, owing to the attempt which has been made to address the suggestions to each city and county individually. It is hoped, however, that the reader may be able to glean from these pages a few suggestions which will assist him in securing better pavements for Wisconsin highways.

The sentiment, so often reiterated, that the coming generation should be satisfied with those conditions which have served the present, is entirely out of harmony with the thought of progressive civilization. The sand, mud and stumps, through and over which some of the people of Wisconsin have driven for years, should be removed, their delight being to make the road smoother and easier for those who will follow the same track.

In buying a pavement, the same principles apply as when a coat is purchased. Shoddy costs less, looks worse, wears out quicker and is more expensive than wool. Use good materials in the construction of a pavement, and ten years hence it will be the best and cheapest.

HIGHWAY CONSTRUCTION IN WISCONSIN.

CHAPTER I.

THE CLASSIFICATION OF HIGHWAYS AND THE AGENTS WHICH DESTROY PAVEMENTS.

In the following pages the terms highway and roadway are used synonymously and refer to any strip of land set apart for travel. The highway is usually separated from the land on either side by fences or hedges. When fully improved it may be separated into three quite distinct parts, known as the road or street, the side-walk or foot-path, and the park or terrace area. The road or street usually occupies the middle and main portion of the highway. On both sides of the road and separated by what is known as the curb is the park or terrace area. Outside of the terrace area on both sides of the highway are situated the side-walks or foot-paths which usually extend to the fence or hedge. The accompanying figure, plate II., shows these parts and their relation to one another.

On the basis of ownership highways may be classified as public and private. Public highways are constructed and maintained by the public through the usual avenues of taxation. Private highways may be subdivided into toll roads and private roads. These are unimportant in Wisconsin and will be given very little consideration in the following chapters of this report. There are a few toll roads in Wisconsin at the present time, but within a few years it is hoped that these will be transferred to

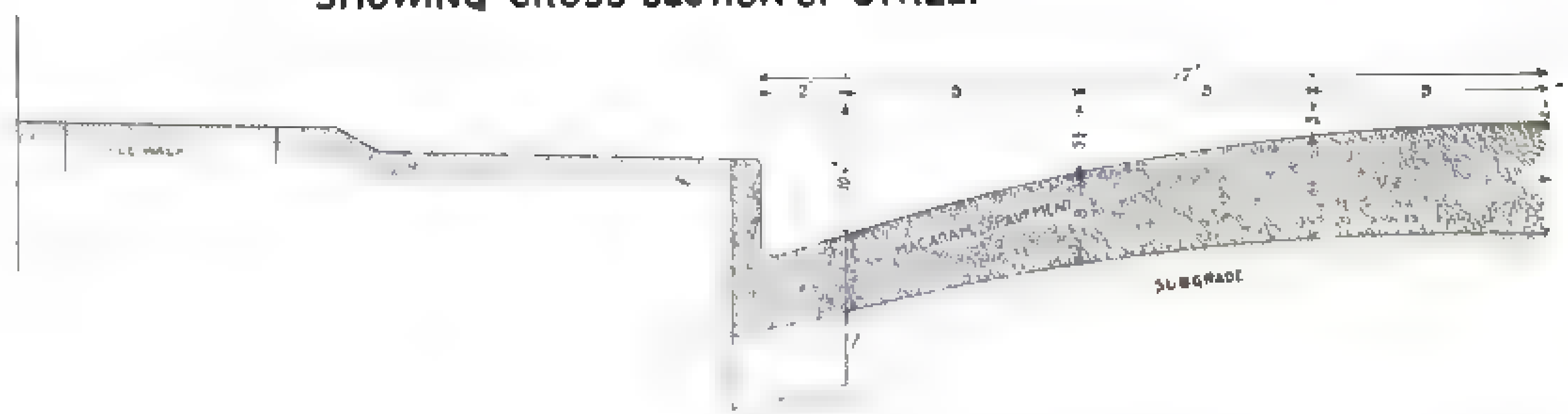
the public. Strictly private roads are such as have been opened at private expense and extend short distances to connect private property with the public thoroughfares.

Public highways may be classified as state, county, town, city and village. The first three are spoken of as country highways and the latter as city streets. It is expected in this report to confine the discussion mainly to city and village highways. Following the Massachusetts Highway Commission, the streets may be classified for convenience into heavy traffic, light traffic and residential.

The width of highways in country districts is determined in Wisconsin by statute and must be either three or four rods, as designated by the supervisors. The width of city highways is determined by the original plat of the land included within the city, town or village limits, and must conform to the statutes governing such matters.

In Wisconsin the highways, both city and country, are sufficiently wide to permit of a considerable variation in the width of the pavement. Depending upon the width of the street, there is considerable variation in the width of the park or terrace areas and the sidewalks. In the case of a very broad highway the proportion which these different parts sustain to one another is controlled by the traffic and the appearance of the roadway when improved. Broad park areas might be so out of proportion to the narrow street which they enclose as to be distasteful to the observer. As a rule, however, the width of the pavement should be controlled by the amount of traffic and not by aesthetic considerations. The traffic on many of the highways in the residence portions of the cities does not require a pavement over twenty feet wide. If the highway is sixty feet wide, five feet on each side should be given up to sidewalks, fifteen feet on each side to park areas, and twenty feet to the street pavement. In the case of a narrower highway, the width of the park areas should be decreased. The tendency at present is to make the street pavements unnecessarily broad, thereby increasing both the cost of construction and the expense of maintenance. The highway should be paved from gutter to gutter and the width of the pave-

PLAN
SHOWING CROSS SECTION OF STREET



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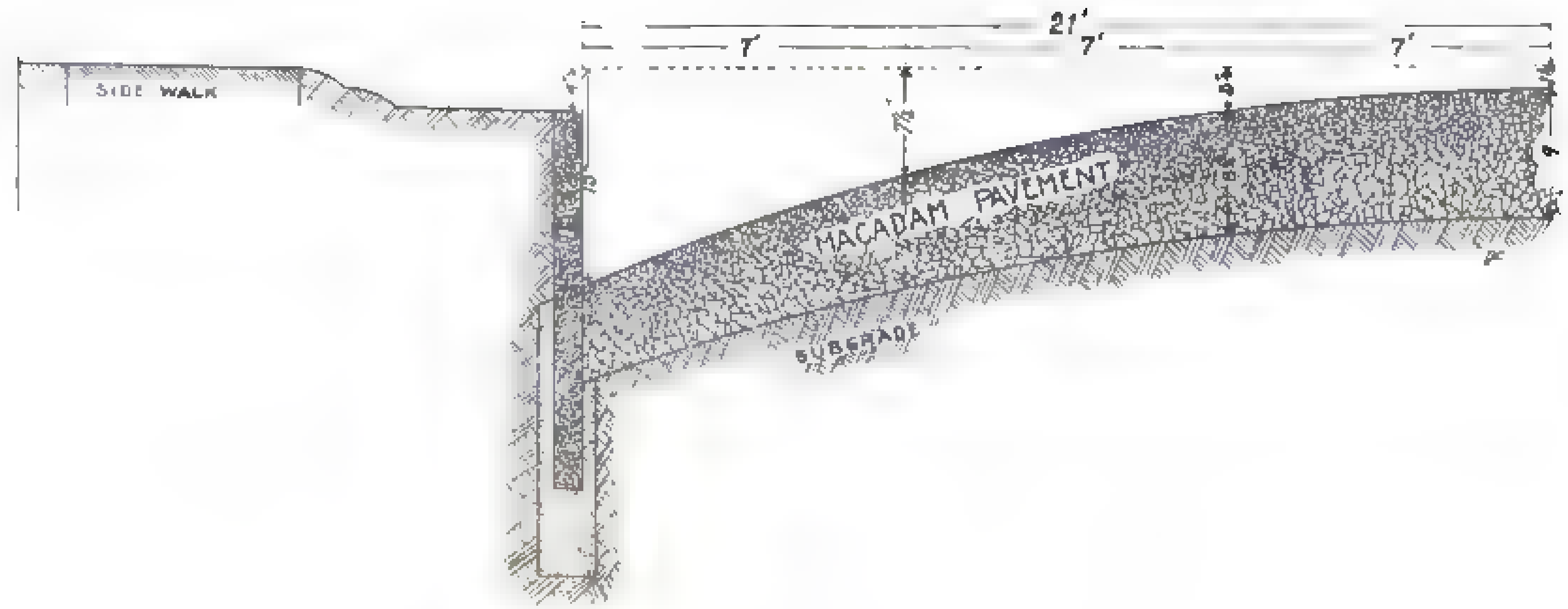

ment should be no greater than is absolutely necessary to accommodate the traffic to which it will be subjected. It should not be inferred from this, that a narrowing of the highway as a whole is advocated. On the contrary, I believe that the streets should be broad and wide, giving light and air and avoiding the dangers of accident incident to narrow roadways. If business should, in years to come, press out and absorb what is now a residence district, it will be an easy matter to give up the park areas in order to increase the width of the pavement. Where wide park areas intervene between the pavement and the contiguous property the valuation of the property is materially increased. The removal of traffic, with its noise and dirt, away from the front yard must in all cases enhance the value of the abutting property.

Theoretically, the perfectly constructed street pavement should consist of the pavement, the gutter and the curb. The sidewalk consists simply of the foot pavement. These,—the pavement, the gutter, the curb and the sidewalk,—may be considered the constructional parts of a highway. As a rule the materials used in their construction must be prepared and often they must be shipped from distant places. The cost of transportation and construction are frequently very great, and for this reason, if for no other, it behooves the authorities to provide the best materials.

Before discussing the materials used in the construction of pavements, in relation to their efficacy to withstand the agents of destruction, let us consider these destructive agents and the manner in which they operate.

AGENTS OF DESTRUCTION.

The agents through which the destruction of a pavement is brought about may be classified as follows:

I. Temperature Changes.

(a) Unequal expansion and contraction of the pavement or its constituents.

(b) Expansion caused by the freezing of water in pores, cavities or crevices in the pavement.

II. Mechanical Abrasion.
- (a) Water
  1. Impact.
  2. Running off from surface.
- (b) Impact and abrasion of horse's hoofs.
- (c) Impact and abrasion of feet of pedestrians.
- (d) Impact and abrasion of wheels of wagons.
- (e) Weight of traffic and abrasion of sleigh runners.
- (f) Internal friction.
- (g) Wind.

III. Growing Organisms.
- (a) Weeds and grasses.
- (b) Trees.

IV. Chemical Decomposition.
- (a) Solution by water.
- (b) Evaporation by the atmosphere.
- (c) Decomposition by acids.

TEMPERATURE CHANGES.

Every pavement is affected more or less by contraction and expansion incident upon variations in the normal atmospheric temperature. Likewise all pavements contain a greater or less percentage of void space into which water finds its way during the wet seasons of the year. The voids may be in the fragments or blocks which go to make up the pavement, or between the fragments or blocks as a result of their irregular shape.

In the matter of pavements we have to deal mainly with stone, wood, brick, concrete, asphalt and coal tar. The rate of expansion and contraction through changes of temperature is, in the case of all of these substances, an appreciable amount and should be considered in the construction of any pavement. I have often seen wide, gaping cracks in asphalt pavements, granolithic (cement) walks, and even in macadam pavements which could only be accounted for by assuming contraction as a result of a lowering temperature.

Mr. W. H. Bartlett has determined experimentally the actual expansion of different kinds of stone brought about by an increase in temperature. He obtained the following results:

Granite, .000004825 inch per foot for each degree Fahr.
Marble, .000005668 inch per foot for each degree Fahr.
Sandstone, .000009532 inch per foot for each degree Fahr.

In this latitude the annual variation in temperature frequently amounts to 150° F., while the diurnal change is often as much as 50° F. A change of 150° F. in the temperature of a sheet of granite 100 ft. in diameter would cause a contraction or expansion of one inch. This is an appreciable amount and would certainly cause a rupture in the sheet were it not free to move. If blocks of granite were closely fitted together and confined on all sides at a temperature of —50° F., and the temperature should be raised to +100° F., the expansive force within the blocks would be so great as to either displace some of their number or break them. If, on the other hand, the blocks should be laid and closely fitted at a temperature of +100° F., and there should be a change to —50° F., sufficient contraction would take place to draw the blocks apart, leaving *interspaces* in the shape of cracks.

In the block or sheet pavements it is necessary that provision should be made for these temperature changes in order to prevent the bulging incident to expansion and the cracking resulting from contraction.

The co-efficient of expansion of asphalt, coal tar, and cement, as used in pavements and walks, has not to my knowledge, been determined. Neither have I been able to find determinations of the co-efficient of expansion of paving brick, wood or asphalt blocks. It is known, however, that pavements constructed out of any of these materials will be subject to injury through changes in temperature unless expansion joints are left in the construction. Asphalt, for example, during hot summer months will become viscous, rolling up in waves before the wheels of a vehi-

***American Journal of Science, Vol. XXII, 1832, p. 136.**

cle. On the other hand, during extreme cold weather cracks have many times been known to form in this pavement.

It was stated above that water might find lodgement in a pavement, either within the pores and interstices or along cracks and crevices which have resulted from temperature changes. Perchance this water fills the pores or cracks during a period of alternate freezing and thawing there is danger of permanent injury to the pavement through the freezing of the water thus retained. If the pavement were made up of loose fragments of rock and the interstices between the fragments should be large, under most conditions the water would be drained off before the temperature lowered sufficiently to cause injury through solidification. On the other hand, if the pavement were almost impervious the interstices would be very small and the water which found lodgment in cracks and crevices would be drained off very slowly. I have made the statement elsewhere,—and it has been substantiated by experiments,—that of two rocks, one of which has very minute pores, and the other of which has large pores, the former will under ordinary conditions be in the greatest danger from alternate freezing and thawing. This is a result of the slowness with which the non-absorbent rocks give up their interstitial water.

It is known that water in passing from the liquid to the solid state expands with an almost irresistible force, exerting a pressure of about 150 tons to the square foot. Thus an ice wedge formed in a crack in the pavement causes a bulging or other slight displacement. These displacements usually occur during the fall or spring, and when the temperature rises during the summer, the expansion is not sufficient to bring together the broken parts. Thus there is formed a permanent channel for the entrance of water at all times.

The danger attendant upon the freezing of water which fills the pores of the rock must not be confused with the danger from the freezing of water, which collects along parting planes. "Compact, thoroughly homogeneous rocks without bedding or other parting planes, whether sedimentary or igneous, are in

less danger from alternate freezing and thawing than those in which these structures exist."*

Alternate freezing and thawing of included water,—both in pores and along fissile planes,—is one of the most potent causes for the decay of stone, brick, concrete, and other similar constructional materials. This agent is especially active at what is known as the water line and must be recognized as one of the most dangerous enemies to the life of a pavement.

Care must be continually exercised to avoid conditions which will result in fissile planes being formed in any part of the pavement. Granting that fissile planes will form at the surface provision should be made for the rapid removal of the water from below. Conditions which result in the retention of the water should be scrupulously guarded against.

The sedimentary rocks as a class are more apt to have parting planes than those of igneous origin and for this reason are more liable to suffer from alternate freezing and thawing. On the other hand the sedimentary rocks may be as free from parting planes as the igneous and in this case are in as little, or even less, danger from freezing.

From the foregoing it is evident that the surface of a pavement should be constructed out of material which is free from fissile planes, and in which such planes will form only under very exceptional conditions. Further, the danger from freezing water enforces upon us the necessity of completely filling the joints in block pavements with a cement mortar which will adhere firmly to the sides of the blocks. In other words, the surface of a pavement,—and especially one in which the pores are of sub-capillary size,—should be impervious to water.

MECHANICAL ABRASION.

Water is one of the most constant agents through which pavements are destroyed. The impact of the drops of rain as they fall on a pavement exert a force which tends to overcome the adhesion between the particles. Unless the pavement is per-

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*Journal of Geology, Vol. VII, No. 2, p. 178, Studies for Students, E. R. Buckley.

fectly constructed, having equal and uniform declivities on both sides of the crown, is free from ridges or depressions and is of uniform hardness and texture, it will not wear uniformly. *Ideal pavements have smooth surfaces; they have the same declivities on both sides of the crown; and the materials in different parts of the pavement are uniform in hardness, texture, and composition.* However, ideally perfect conditions are seldom if ever obtained. The nearer we approach these conditions the less will be the efficacy of the water in destroying the pavement. The wear occasioned by the water which flows off from the surface is accomplished by the material held in suspension. Therefore *the less debris that the water can pick up in flowing off from the surface, the less will be the wear. The shorter the distance that the water has to flow in passing from the surface of the pavement to the gutter, the less will be the wear.* A dirt road after a heavy rainstorm is often cut up with innumerable small and large channels formed by the water in its passage from the center of the road to the gutter.

Everywhere, the erosion of the land is accomplished by the circulation, in channels, of the water which falls on its surface. The formation of streams is accounted for mainly by inequalities in the hardness of the rocks and unequal declivities of the surface. The rate of erosion is controlled in part by the velocity of the stream and the amount of sediment which it carries. A clear stream or one which is overloaded does little work. Thus the water which falls on a pavement, in order to deepen the channels or ruts in which it flows must be provided with tools in the shape of sand or gravel picked up at the surface.

If we would reduce to a minimum the effect of the rainstorm, we should construct the pavements out of homogeneous materials which are not easily eroded—those which are hard and compact. They should also be constructed in such a manner as to convey the water off from the surface by the shortest course and without collecting it into rivulets.

Abrasion is also brought about by the impact of the horses' hoofs as they strike the pavement. The impact may simply oper-

ate as a rasp overcoming the adhesion which binds together the particles at the surface, or the impact may result in cracking or breaking portions of the pavement. In any case the resulting deterioration of the pavement is very great.

The character or manner of abrasion differs between the various pavements. A macadam or sheet pavement such as asphalt or tar macadam usually wears gradually,—the softer portions most rapidly. A block pavement, unless the joints are completely filled with cement, presents numerous corners and edges which may be split off by any sharp blow, such as the impact of a horse's hoof. Brick, stone block, asphalt block and similar pavements suffer in this manner. The simple abrasion of a pavement increases as the conditions for sliding become more favorable. A smooth, sloping pavement increases the amount of sliding on the part of the horses. As the blocks of a block pavement become rounded at the surface the sliding action increases within the narrow limits of the block. Granite blocks often become rounded and polished at the surface through the abrasive action of the iron horseshoes as they slide into the joint to secure a foothold.

Wagon wheels wear a pavement mainly through impact resulting from unevenness in the surface of the pavement. The end edges of brick and stone blocks are broken mainly by the impact of the wheels, while the side edges are broken mainly by the impact of the horses' hoofs. A perfectly level pavement suffers very little wear from the wheels, either through impact or friction. Sleigh runners occasionally cut through the snow onto a pavement and act as rasps, wearing more or less that portion of the pavement with which they come in contact.

The load carried by transfer and other wagons is sometimes very heavy. This dead weight which a pavement is called upon to sustain occasionally crushes either the surface or the foundation of the pavement. This crushing may break the pavement or foundation into blocks similar to those formed when a sheet of ice is similarly treated. In other cases where the surface is soft, the wheels sink into the pavement forming ruts. Again the pressure may result simply in the dislocation of certain blocks.

In any event the impact and abrasion, both by the steel hoofs of the horses and the wheels of the vehicles, are made more effective in proportion to the weight of the load.

Only where the fragments composing the pavement are loosely cemented and free to move is internal friction an important agent of mechanical wear. This wear is most frequent in broken stone pavements where the interstices between the angular fragments are left void and loose. The rubbing together of the fragments under the pressure of moving vehicles has a tendency to round off the corners on account of which they may lose a great part of their bonding capacity. Gilispie says in this connection: "If a thick coat of crushed rock be laid on at once there is very great destruction of the material before it becomes consolidated, if it ever does so. The stones will not allow one another to be quiet, but are continually elbowing each other and driving their neighbors to the right and to the left. This constant motion wears off the angular points and reduces the stones to a spherical shape, which, in conjunction with the amount of mud and powder produced, destroys the possibility of any firm aggregation, and the road never attains its proper condition of hardness." From these observations one can readily appreciate the necessity for constructing an immovable pavement or one in which internal friction between the component parts is reduced to a minimum.

Wind as well as water is an active agent of erosion and in this capacity has an influence on the permanence of a pavement. Drifting sand or dust, carried forward by the wind, slowly abrades the surface of the pavements. This manner of wear proceeds slowly in Wisconsin, but combined with the work of the other agents, it assists in the eventual complete disintegration of the pavement.

GROWING ORGANISMS.

Grass and weeds growing along the roadside have both a protective and destructive influence on a pavement. The nature of some of the pavements is such that neither grass nor weeds will

grow on their surface. Macadam, wooden block, stone block and brick,—each sometimes provides a foothold for vegetation. If given a chance vegetation will completely cover a macadam pavement or crowd the joints of a block pavement with tufts of weeds and grass.

Grass growing on the surface of a pavement protects it from the abrading action which accompanies the removal of the rain water. It also collects and retains the detritus which would otherwise be removed. The roots penetrating between the blocks promote disintegration through their expansion, and the retention of moisture and the acids resulting from the decay of the vegetation, all serve to hasten the ultimate destruction of the pavement.

Outside of the actual injury which results to the pavement through the growth of grass and weeds, the ragged fringe which they make as they fill the gutter and sometimes the street, is most distasteful to one who has a sense of beauty and cleanliness.

The shade tree is also one of the agents which contributes to the destruction of pavements. Mr. Law in his publication on "The Art of Constructing Common Roads" says: "Few persons are aware of the extent to which a road may be injured by high hedges or lines of trees. Trees are worse than hedges because they not only deprive the road of the action of sun and air, but they further injure it by dripping rain from their leaves, as a consequence of which the road is kept in a wet state long after it would otherwise have become dry." He further adds, "* * * from an engineering point of view everything that interferes with the sun and prevents the circulation of air is objectionable." We cannot, however, meet in all respects the ideal conditions of the engineer. Hedge fences may be necessary in some sections of the country, although they are not required in the cities. In the southern states, hedge fences are very common, but they have proven so expensive in every way that they are being rapidly replaced with wire. Everywhere there is an increasing demand for shade trees and the remedy for their destructive influences must come through the charac-

ter of the pavement constructed and not through the removal of the trees.

Some classes of sidewalks and also pavements are bulged and broken through the expansion caused by the rapid growth of tree roots. The danger from this source should never be removed by cutting down the trees. It must be avoided by a proper construction of the pavement and a deeper planting of the trees. Avoiding injury from the growth of shade trees is mainly a problem of the city, while the question of hedges belongs almost exclusively to the rural districts. In cities where the highway is broad enough to allow a portion of it to be devoted to park areas the shade trees are usually sufficiently removed from the pavement to warrant very little consideration. However where the highway is narrow they have an influence which should not be disregarded.

CHEMICAL DECOMPOSITION.

Wherever rain water carrying an excess of carbon dioxide and humus acids soaks into a pavement, there is greater or less danger of chemical reactions taking place. If a pavement has asphalt, limestone, or coal tar constituents, there is a greater possibility of chemical action taking place than where the pavement consists of granite, sandstone, brick and cement. Naturally this is due to the varying degrees of stability of the materials named. Asphalt and coal tar pavements, especially, will disintegrate if water is allowed to stand continually on their surfaces.

Evaporation by the atmosphere takes place mainly in connection with asphalt and coal tar pavements. The extent to which this process goes on depends very largely upon the composition of the pavement. Some of the coal tar used has evaporated so rapidly as to leave a mass of loose fragments within a few years from the time the pavement was constructed. Asphalt on the whole evaporates much more slowly than coal tar,—yet evaporation takes place at a sufficiently rapid rate to be appreciable during the life of the pavement.

Resumè.

It would be difficult to say which of the agents of destruction is most active in Wisconsin. They are all operative but vary in intensity, depending upon their location. There is no doubt that on Chestnut street, in Milwaukee, the most potent cause for the rapid decay of the brick pavement is the heavy character of the traffic. The same kind of pavement on another street might deteriorate more through the influences of the weather than on account of the traffic. The character of the pavement itself, the condition of the subsoil and the nature of the drainage may each effect the activity of these agents.

The traffic, subsoil and drainage conditions often vary greatly in different parts of a city, but the climatic conditions remain substantially the same. The only changes in the atmospheric conditions that may be properly considered are those which exist between the northern and southern parts of the state. Seasons in which thawing and freezing alternate many times are the most dangerous to pavements. One needs to fear but little the excessive cold in the northern part of the state if the surface is covered with an abundance of snow.

The atmospheric conditions are considered but very little in the selection of pavements in most of the cities of Wisconsin. The cost and the character of the traffic usually control.

CLASSIFICATION OF STREETS.

Depending upon the character of the traffic which passes over the streets of a city, they have been divided into the following classes:

I. Heavy traffic.

II. Light traffic.

III. Residential traffic.

Heavy traffic streets usually occur in close proximity to warehouses and depots, along wharfs, next to wholesale and extensive retail houses and near manufacturing plants. The pavements on such streets are usually selected for their capacity to sustain heavily loaded vehicles.

The light traffic streets are subject to a greatly varying traffic, some of which is very heavy but most of which is light. The pavement, however, must be built sufficiently strong to sustain the occasional heavy vehicles which pass over its surface. It is not required that such a pavement shall be strong enough to sustain *continued* heavy traffic.

The residential traffic street is practically free from heavy traffic and consequently is usually improved with a pavement which is selected with little regard for its capacity to withstand heavy traffic. Beauty, cleanliness and noiselessness are the most important characteristics of a pavement selected for such streets. Each of these will be discussed in its turn in subsequent chapters.

CHAPTER II.

MATERIALS USED IN IMPROVING HIGHWAYS.

There are a great enough variety of places and diversity of conditions in Wisconsin, to call for the use of almost all of the different materials that enter into the improvement of highways. The kind of material used usually controls the degree of permanence of the pavement, and the use of any but the pavement best adapted to the conditions is usually a result of limited funds or ignorance on the part of the public officials.

The existing conditions are such that almost all substances both vegetable and mineral are used somewhere, in some place, for the improvement of the highways. Straw, corn stalks, hay, boards, logs, brush, saw dust, bark, shavings, stone, gravel, sand, clay and many artificial products are used for the improvement of the highways. In this discussion, however, we are considering the more permanent classes of street pavements into the construction of which many of these materials do not enter.

The materials which are used in permanent street improvements may be classified as (1) natural and (2) manufactured. The most important natural materials used in highway construction are sand, clay, gravel, wooden blocks, shells and stone including sandstone, limestone, shale, slate, granite, quartzite, trap rock, and asphaltic sandstone and limestone. The principal manufactured or refined products are cement, coal tar, asphalt, gumbo, brick, oil, cinders, slag, iron pipe, vitrified sewer pipe, cement pipe, drain tile, glass, charcoal, and asphalt blocks. Each of these has its own peculiar characteristics which best

fit it for use in different parts of the various pavements. In the following pages each of these products will be taken up alphabetically and considered with special reference to its suitability for use in the construction of the different pavements.

ASPHALT.

Asphalt has a black or brownish color and is brittle when struck a sharp blow with a hammer. It melts at a temperature of about 200° F. Grahamite, gilsonite, uintaite and albertite are varieties of asphalt.

Asphalt is the oxide form of mineral tar known as ozokerite. Ozokerite is an oxide form of petroleum, while petroleum is formed from naphtha through the loss of volatile matter. Asphalt occurs in beds and veins or impregnating porous limestone and sandstone. The purest and most extensive deposit of asphalt known occurs on the Island of Trinidad near the coast of Venezuela. The asphalt at this place occupies a basin in the form of a lake covering 116 acres. The most important asphalt deposits in the United States are found in California. Here the asphalt occurs either in irregular veins or impregnating beds of sandstone. Kentucky, Texas and Utah have also produced asphalt in commercial quantities. Asphaltic limestone and sandstone, similar to that which is mined in California, occur in Indian Territory, Arkansas, western Missouri and eastern Kansas.

Asphalt is used extensively in the construction of sidewalks and street pavements. In these constructions it is always mixed with other constituents among which are sand, oil and crushed stone. Where sheet or rock asphalt pavements are constructed, the process of mixing is carried on in the street adjacent to where the pavement is being laid. Where asphalt blocks are used, the manufacturing process is conducted at factories erected for this purpose. Asphalt is also used as a cement or grouting for filling joints in block pavements.

Asphalt from different localities varies greatly in its composition and consequently in its capacity to withstand the agents

of destruction. It is ordinarily known as mineral pitch and consists of a mixture of partly oxidized hydro-carbons. Crude asphalt is composed of several different substances as shown by the following tables representing analyses of crude Trinidad asphalt:

*Analyses of crude Trinidad asphalt.**

	Per cent.	Per cent.	Per cent.
Water	16.37	27.85	27.85
Asphalt	39.83	38.14	38.14
Earthy matter	33.99	26.38	34.01
Vegetable matter	9.31	7.63	
Total	100.00	100.00	100.00

Before being used the crude asphalt is refined. By this process the water, earth and vegetable matter are removed. The following table gives the chemical composition of refined asphalt from a number of different localities:

*Analyses of refined asphalt.**

Place.	Trinid'd.	Mexico.	Peru.	Cuba.	Col'mbia	Palest'ne
Chemist.	Bowen.	Regault.	Bossingault.	Bossingault.		Kayser.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Carbon	85.89	80.34	88.67	81.50	88.31	80.00
Oxygen	.56	10.09	1.65	6.60	1.68	.40
Hydrogen	11.06	9.57	9.68	9.60	9.64	9.00
Nitrogen	....	....	....	....	.37	10.00
Sulphur	2.49	....	....	....	....	.60
Ash	....	....	....	....	....	....
Total	100.00	100.00	100.00	100.00	100.00	100.00

Asphalt can be recognized by its physical as well as by its chemical properties. It has a brownish black to black color, a bituminous odor and a lustre resembling that of black pitch. It

* "Mineral Industry," Vol. II, page 45.

has a specific gravity 1 to 1.8; ordinarily melts at a temperature of from 90 to 100° Fahr.; burns with a bright flame; and is almost entirely soluble in turpentine and partly soluble in alcohol. "The action of heat, alcohol, ether, naphtha and oil of turpentine, as well as direct analyses, show that the so-called asphaltum from different localities is very various in composition. The following are the classes of ingredients present.

(A) Oils vaporizable to about 100° or below, sparingly present, if at all; (B) heavy oils probably of the pittolium or petrolene groups, vaporizable between 100° and 250°, and constituting sometimes 85% of the mass; (C) resins, soluble in alcohol; (D) solid asphalt-like substance or substances, soluble in ether and not in alcohol; black, pitch-like, lustrous in fracture; 15 to 85%; (E) black or brownish black substance or substances not soluble either in alcohol or ether; similar to D in color and appearance, Kersten; brown and ulmin-like, Völckel; 1 to 75%; (F) nitrogenous substances; often as much as corresponds to one or two per cent. of nitrogen."*

From an examination of the above, one can readily see how difficulties might arise in using asphalt from different localities unless the utmost precaution is taken. Some of the precautions to be observed in the use of asphalt are enumerated in a subsequent chapter. In selecting asphalt for street paving, one should know the composition and permanent cementing qualities of the different brands that are under consideration. Their solubility in carbon disulphide, in alcohol, in turpentine, in ether, in petroleum and in naphtha should also be determined. It is likewise important to know the softening point and the temperature at which the asphalt flows.

At a temperature of less than 70° Fahr. it is supposed that asphaltum will remain unchanged. There are very few localities, however, where a higher temperature is not reached during some period of the year. When a temperature above 70° is reached, asphalt slowly volatilizes. During the summer months in the temperate zone this temperature is often reached and disintegration through volatilization must take place.

*A System of Mineralogy, E. S. Dana, 1899, page 1018.

Asphalt Pavement. Intersection of Chestnut and Third Streets, Milwaukee, Wis. Shows the effect of heavy traffic.

BRICK.

Two kinds of brick are used in street improvements in Wisconsin cities, viz., sewer brick and paving brick. Paving brick can be used for sewer purposes, but sewer brick cannot be used successfully for paving.

Sewer brick made in Wisconsin differ greatly in quality in different localities. They are usually a hard, semi-vitrified product which is taken from the arches of up draft and from the top of down draft kilns. Any non-porous hard brick manufactured by any process is called a sewer brick and passes on the Wisconsin market as such.

Sewer brick are frequently used for sidewalks and sometimes for paving. It is very seldom, however, that these brick prove as satisfactory for these purposes as the regular paving brick. Nothing but a thoroughly and uniformly vitrified brick is capable of withstanding the abrasion to which a sidewalk or street pavement is subjected.

During the last ten years vitrified brick have been increasing in importance as a material for both street pavements and sidewalks. Their suitability for these purposes will be discussed in a subsequent chapter where brick pavements are considered.

Vitrified brick are manufactured from a combination of shale and clay similar to that which is used for the manufacture of vitrified sewer pipe. The following is the composition of the clays used by several well known companies for manufacturing paving brick:

Composition of clays used in manufacturing paving brick.

	I.[1]	II.[2]	III.[3]	IV.[4]
SiO_2	68.96	61.76	60.34	57.30
Al_2O_3	17.95	18.32	24 26	21.29
H_2O combined	....	2.94	1.56	6.00
H_2O moisture	....	....	....	1.30
Fe_2O_3	7.25	2.01	7.73	7.21
Ca O	0.76	....	1.35	0.29
MgO	1.47	1.45	0.70	1.53
K_2O	2.38	3.49	3.12	3.44
Na_2O	....	....	....	0.61
Miscellaneous	1.05	....	....	....
Grand total	100.00	100.00	99.16	99.97
Age	Coal meas.	Coal meas.	Coal meas.	Coal meas.

[1] No. I—From Galesburg, Illinois, Clay Worker, April, 1895 (Meade), Indianapolis.
[2] No. II—From Streator, Illinois, Clay Worker, April, 1895 (Meade), Indianapolis.
[3] No. III—From Des Moines, Iowa, Clay Worker, April, 1896 (Meade), Indianapolis.
[4] No. IV—From Canton, Ohio, Clay Worker, May, 1894, Orton, Indianapolis.

The quality of the paving brick does not depend entirely upon the kind or composition of the clay or shale used in their manufacture. The greatest care must be taken in the preparation of the clay and in the drying and burning of the brick. In the process of burning, the temperature is increased very gradually and raised to a point where the vitrification of the clay is complete. The temperature within the kiln should be uniform throughout and the brick at the bottom and top of the kiln should attain as nearly as possible the same degree of vitrification. It is true that absolute uniformity in the degree of vitrification has never yet been obtained in all parts of a kiln, but in some this condition is more nearly attained than in others.

Owing to the difference in the perfection of vitrification in different parts of a kiln, the brick are usually sorted into two or three different grades, called Nos. 1, 2 and 3. No. 1 brick are made to include those that are neither under nor over burned, having a perfect shape and thoroughly vitrified; No. 2 include brick that have not been completely vitrified, but are uniform and rectangular in shape. No. 3 brick include those

that have been distorted in shape and others having their corners broken or chipped. The over burned brick are ordinarily known to the trade as "clinkers".

The brick in any two kilns may be burned very differently. Brick from the first kiln may be mainly No. 1, while those from the second kiln may be largely No. 2. Owing to the possibility of careless or loose grading of the brick from any one yard, as well as the difference in the standard hardness of brick from different yards, it is very important that each lot of brick obtained for street paving should be thoroughly tested before being accepted. A No. 1 brick should be perfect in shape without any sign of warping or cracking. It is not sufficient that a No. 1 brick should have square corners on one side; it should possess square corners on all sides. A brick which is in any way broken, fractured or distorted, should be classed as No. 2 or No. 3. This has not been the practice among the brick manufacturers. The inspectors have usually permitted the laying of brick which have only the upper side free from fractures and from broken edges and corners.

Assuming the brick to be perfect in shape, it is necessary that one should determine its strength and durability by a series of laboratory tests. These tests include a determination of the specific gravity, porosity, crushing strength, transverse strength, hardness and capacity to resist abrasion. If one expects to obtain the very best results from a brick pavement, it is very important that all of these tests should be made in selecting the kind of brick to be used. City engineers, as a rule, pass judgment on the quality of various paving brick after determining the absorption, hardness and capacity to resist abrasion. The hardness can be tested by using Moh's scale of hardness. The absorption can be obtained by saturating the brick in water and weighing on a pair of chemical balances. The loss due to abrasion can be determined by placing a half brick in an abrading machine known as the "Rattler". This machine is usually a polygonal cylinder from 24 to 30 inches in diameter with a length of 36 to 42 inches. The machine is revolved at a rate of about 25 revolutions a minute for about an hour when the

brick are taken out and the loss in weight determined. In making a test at least from 5 to 10 brick should be used.

A vitrified brick has a hardness of between 6.5 and 7, which is midway between the hardness of feldspar and quartz. A well vitrified brick should not absorb more than two per cent. of water. A common hard burned brick often absorbs from 5 to 10 per cent. of moisture, while an imperfectly vitrified brick frequently absorbs as much as 6 per cent. of moisture. The porosity test is usually made by soaking a thoroughly dry brick in distilled water for 24 hours. The weight of the water absorbed divided by the dry weight of the brick is taken as the porosity. A porosity of more than 2 per cent. is considered by some engineers as certain evidence that the brick will not be capable of withstanding exposure to the weather. This inference is not altogether correct and, in some cases, it has been clearly demonstrated that a brick having 4 or 5 per cent. of pore space is as little injured by temperature changes as one in which the pore space is under 2 per cent.

The specific gravity of vitrified brick ranges from 2.20 to 2.40. Although the crushing strength of a thoroughly vitrified brick frequently runs as high as 20,000 lbs. per square inch, a paving brick which will stand a pressure of over 6,000 lbs. per square inch is considered sufficiently strong for all ordinary pavements.

The cross breaking strength of a paving brick, which is expressed by the modulus of rupture, should range from 1,000 to 3,000 lbs. per square inch. A less modulus of rupture is permissible for most pavements and it very seldom happens that a brick has not a sufficient cross breaking strength to withstand any load which it may be called upon to sustain.

The capacity which a brick has to withstand abrasion is one of its most important qualities. A great many tests on brick from many different factories show that brick lose from 5 to 15 and in exceptional cases 50 per cent. Most engineers specify that the brick used in street paving shall not show a loss of more than 10 per cent. when subjected to a test of one hour in a standard rattler. The percentage of loss depends upon the

quality of the brick and the manner in which the test is conducted.

There are several kinds of rattlers in use in the United States and each of them is so constructed that the results obtained from one cannot be compared with those from another. There are also different methods of using the same rattler on account of which it often happens that tests made in the same kind of a machine cannot be compared. Further than this, no rattler has yet been built which represents the conditions of wear which actually exist in a pavement.

The common method of determining the abrasion or wearing quality is to place several brick in a cast iron cylinder along with from 5 to 15 lbs. of scrap iron. The cylinder is such as is ordinarily used for cleaning castings and does not exceed 24 to 28 inches in diameter. The cylinder is revolved slowly, at a rate of about 15 to 25 revolutions per minute. The iron used consists of pieces of irregular shapes and sizes, not exceeding one-fourth of a pound in weight. Each engineer has taken such scrap iron as was at hand and made his tests, which have value, only when compared with tests made in the same machine and with the same iron. The National Brick Makers' Association have adopted this as the standard test, using iron blocks of definite size and shape instead of scrap iron. With this improvement there ought to be much greater uniformity in the tests. Attempts have been made to obtain the quality of different bricks by placing several of each kind in a rattler together with and without scrap iron. This method is unsatisfactory, owing to the difference in the weight and degree of hardness of the brick to be tested.

A rattler or tumbling barrel has been built lately, in which the brick to be tested constitute the inside lining to the barrel. Loose iron blocks are placed in the barrel and as it revolves they drop upon the exposed faces of the brick. The impact of the blocks on the brick corresponds to the pounding of the horses' hoofs as well as the impact of the wheels of a vehicle. This machine has several advantages over the others and may eventually supersede them in making abrasion tests.

From the above it will be seen how difficult it is to make any statement as to what per cent. of loss a brick should sustain in an abrasion test. A uniform method of determining the wearing quality of paving brick should be adopted in order that comparative tests may be obtained.

CEMENT.

Cement has become one of the most important materials entering into the construction of permanent pavements.

Cement is composed of a mixture of alumina, silica and calcium carbonate in more or less definite proportions, depending upon the kind of cement manufactured. Calcium carbonate is the most abundant constituent and as used occurs either in the form of limestone or marl. Alumina and silica are supplied by the clay or shale. These three necessary ingredients, calcium carbonate, clay and silica, frequently occur in nature in approximately the correct proportions for the manufacture of cement. Where such is the case the stone thus formed is commonly known as hydraulic limestone. From this limestone natural cement may be manufactured. The strength and quality of the cement thus obtained depends mainly upon the nearness with which the constituents approximate the theoretically correct proportions for cement.

Scientific investigation has shown that the best cement is obtained by mixing and burning definite proportions of alumina, silica and calcium carbonate. These constituents are obtained separately, the alumina and silica from clay or shale, and the calcium carbonate from limestone or marl. Cement which is made from a mixture of clay or shale and marl or limestone is called portland cement.

The following table gives the composition of a few typical limestones, marls and clays used in the manufacture of portland cement:

*Analyses of limestone and marls.**

	Chalk, England (Reed).	Cement rock, La-Salle, Ill.	Cement rock, Siegfried, Pa.	Marl, Sandusky, Ohio.	Marl, Syracuse, Ind.
Calcium carbonate	98.57	88.16	69.91	91.77	88.49
Magnesium carbonate	0.38	1.78	4.28	0.53	2.71
Calcium sulphate	....	.. ..	....	3.19	1.58
Silica	0.64	8.20	17.32	0.22	1.78
Alumina	0.16	1.00	7.07	1.22	0.91
Iron oxide	0.08	0.80	2.04	0.40	0.39

*Analyses of typical clays.**

	Medway, Eng.	Harper, O.	Sandusky, O.	La Salle, Ill.
Silica	70.56	51.50	65.41	54.30
Alumina	14.52	13.23	16.54	19.33
Iron Oxide	3.06	3.30	6.06	5.57
Lime	4.43	11.52	2.22	3.29
Magnesia	....	3.45	1.88	2.57
Carbonic acid	3.47	12.85	....	....
Alkalies	3.95	....	....	....

Outside of the method of manufacture, the strength and durability of a cement depend mainly upon the absence of impurities in the raw ingredients. For example, it is claimed by some that more than four per cent. of magnesia is injurious, to the extent of producing an inferior cement.

The comparative tensile strength of portland and natural cement is given in the accompanying table.

* "The Cement Industry," The Engineering Record, 1900, pp. 12-13.

*Tensile strength of cement-mortar.**

Composition of the Mortar.		Age of mortar.							
		Rosendale (Natural).				Portland.			
Cement.	Sand.	1 Week.	1 Month.	6 Mos.	1 Year.	1 Week	1 Mo.	6 Mos.	1 Year.
1	....	100	180	275	300	300	400	450	500
1	1	60	100	170	224	175	250	340	375
1	2	25	60	125	170	120	150	245	290
1	3	20	40	80	120	90	110	175	220
	4	15	25	60	90	75	75	130	170
	5	10	15	50	80	60	65	110	130
1	6	6	10	45	75	50	36	90	100

Cement testing.—Among the common tests made to determine the quality of different cements are specific gravity, fineness, setting property, tensile strength and soundness. The methods of making these determinations and their value are discussed in nearly all text books treating of this subject. The Chemical Publishing Company of Easton, Pennsylvania, have lately published a small volume on the "Examination of Portland Cement", by Richard K. Meade, which brings together in concise form much valuable information on this subject. The reader is referred to that volume for information on analyzing and testing cements.

Two cement factories are located in Milwaukee each of which is engaged in manufacturing natural cement from what is known as the Hamilton Lime Rock. The cement which is produced by these factories is equal, if not superior, to any natural cement manufactured in the United States.

For several years there has been a movement looking toward the erection of a portland cement factory in Wisconsin, but up to the present time none have been established.

In highway construction cement is now used in making concrete foundations to asphalt, brick, stone block, wooden block and asphalt block pavements; in the manufacture of sewer pipe,

* Highway Construction, 1900, A. T. Byrne, p. 278.

curbs, gutters, granolithic walks, sewers, catch basins, cross walks and as grouting filling the joints in block pavements. In concrete foundations and for sewers and catch basins one can use natural cement without danger, but in the construction of curbs, gutters, granolithic walks and cross walks, as grouting for block pavements and in the manufacture of sewer pipe, portland cement is preferable.

CEMENT PIPE.

Cement sewer pipe of all sizes and of the most approved shapes is manufactured in Wisconsin. The pipe is made out of the very best natural cement, gravel and sand. It is practically impervious and when properly made should be equal to most vitrified clay pipe.

Wherever strength, durability and cheapness are the only considerations, cement concrete is superceding brick and similar structural materials. Tunnels, large sewers and other underground constructions are now being built mainly out of concrete.

Two companies are now engaged in manufacturing cement sewer pipe in Wisconsin. They are "The Whitnell, Rademaker Co." and "H. Berthelet Sewer Pipe Company," both of Milwaukee. Formerly other factories were operated in Racine, Oshkosh, Appleton and Wausau. To the best of my knowledge, these factories have been discontinued.

CHARCOAL.

In some countries charcoal has been used for making temporary improvements to the highways. I do not know that it has ever been used in Wisconsin and do not believe that it ever will be. In the absence of slag or cinders it might be used successfully as a foundation for cement or granolithic walks and gutters.

CINDERS.

Cinders are no longer used for the construction of permanent pavements. They are employed mainly in making foot paths,

repairing temporarily unimproved streets and for foundations to cement walks and cement curb and gutter. In the construction of cement or granolithic walks, curbs and gutters, they constitute one of the very best materials for the foundation.

Cinders are obtained mainly from manufactories, railroads and other concerns using coal for fuel. Usually they are given away but in some places a small charge is made for them. Soft coal cinders which make a small clinker are most desirable.

CLAY.

Clay in its pure form is known as kaolin. Chemically it is a hydrous aluminum silicate. In the vernacular of highway construction it is a plastic earthy mass consisting of kaolin, quartz, iron oxide, calcite and other minerals in variable proportions. Some of the clays as thus known are very plastic while others are only weakly so. With the Wisconsin clays, the plasticity or stickiness usually increases and decreases with the percentages of kaolin, calcite and dolomite. The value of clay in road building rests mainly in its so-called cementing property on account of which it hardens upon drying. The clay of a clay-sand road binds the sand grains together, making a moderately smooth, hard surface in dry weather. Sand mixed with clay decreases the plasticity or stickiness of the clay thereby making a harder road during wet weather. Clay mixed with sand decreases the dust, making a harder road during dry weather.

The value of raw clay as a road material is mainly as a binder for gravel and broken stone. A clay which is ferruginous is most suitable for this purpose. The percentage of clay required for bonding gravel most satisfactorily will depend upon the composition and properties of the clay. Twenty per cent. of clay which is moderately free from impurities is usually about the correct proportion of a mixture of gravel, clay and sand.

In the construction of permanent pavements, raw clay plays a very unimportant part. Occasionally it is used in building macadam pavements, but even here it should not be used if it is possible to bond the pavement without it. Brick, drain tile,

sewer pipe, curbing and gumbo,—manufactured products of clay,—are very important materials for road constuction. These are discussed elsewhere in this chapter.

COAL TAR.

Coal tar is a by-product resulting mainly from the manufacture of charcoal, coke and gas. The nature of the tar varies with the character of the coal and also with the process employed in manufacturing the gas, coke or charcoal. The amount of bitumen in coal tar varies from 60 to 92 per cent. The quantity and quality of the oil contained in the tar also varies. The non-bituminous matter, which is usually in the form of carbon, also varies in quantity.

The coal tar cement which is used in street constructions is a residuum from the distillation of the crude coal tar. The proper consistency or hardness of the tar is obtained by removing a portion of the oils by distillation. The amount of oil removed at any given temperature depends upon the nature of the oil. The temperature at which coal tar can be distilled depends upon the content of oil.

As in the case of asphalt, skill and experience are necessary in the selection of any coal tar to be used in street constructions. A knowledge of its purity and chemical composition as well as its physical characteristics are necessary in the selection of a suitable brand for work of this character. Care in the selection and compounding of the materials to be used with the coal tar is also essential. This will be discussed more at length under tar macadam pavements in another chapter.

DRAIN TILE.

Drain tile may be manufactured out of most moderately plastic clays such as occur along the west shore of Lake Michigan. The color of the tile depends upon the amount of iron, lime and magnesia in the clay. Drain tile are intended to be porous and vitrification defeats the purpose for which they are intended. They should be well burned, however, and strong enough to withstand rough handling and severe freezing.

Red, white, cream and mixed colored tile are manufactured in Wisconsin. They are manufactured in all sizes from 2½ to 12 inches in diameter. The standard length is 12 inches. The Bristol Brick and Tile Company, Bristol, the Springfield Brick and Tile Company, Springfield, the Burlington Brick and Tile Company, Burlington, the Jefferson Brick and Tile Company, Jefferson, the Cook and Brown Lime Company, Oshkosh, the Frenzel Brick and Tile Company, Oakfield, the Dencon Brick and Tile Company, Denoon, the Wind Lake Brick and Tile Company, Wind Lake, the Elkhorn Brick and Tile Company, Elkhorn, the North Cape Brick and Tile Company, North Cape and other companies are manufacturing an excellent drain tile suitable for draining all conditions of land.

In street construction it is frequently very important to use the ordinary tile drain to remove the water from an exceptionally wet portion of the road. Sometimes a tile drain laid through the center of the street and several feet below the surface of the pavement will be entirely sufficient to remove the surplus water and keep the pavement dry. Cross drains are also laid in some places with equally satisfactory results. It is very important that the drains should be carefully laid. The importance of tile drainage in road construction is but little appreciated and should be given more attention by city engineers.

GLASS.

In Europe glass is now being manufactured into blocks for street paving and it is reported to be very satisfactory for this purpose. It has long been used for sidewalks and in this capacity has proven its suitability. It is reported that in strength and hardness it equals many of the stone blocks now used in the large cities. A pavement constructed out of these blocks is said to be quieter than one built out of stone. A glass block used for paving must be tough and strong.

Glass blocks are now manufactured exclusively in European countries but there is no reason why they cannot be produced in Wisconsin. There is an abundance of raw material easily

available. Silica and lime, the two essential ingredients, are found in Wisconsin in unlimited quantities.

GRAVEL.

Gravel is a term applied to any accumulation of pebbles brought together either by water or ice. The fragments usually have roundish or sub-angular outlines, although their shape depends very largely upon their hardness and the length of time that they have remained in the water or ice. Gravel may consist of any of the numerous varieties of rock, although flint, limestone, slate, quartzite, granite and greenstone are the more common. There is no limit to the size of the pebbles and they may range from sand grains to boulders twelve inches or more in diameter. The pebbles which make up a gravel bank, are usually under four inches in diameter. When the gravel contains fragments that exceed two and one-half inches in diameter it should be either screened or crushed before being used for road work.

The gravel in Wisconsin is obtained from three sources,—the rivers and lakes and residual and glacial deposits. The gravel of the lake and stream deposits is, as a rule, smoother and better rounded than that of the glacial deposits. The stream and lake gravel is also, as a rule, cleaner than that deposited by the ice. Stream and lake gravels are usually composed of pebbles which have been derived either from the adjacent country rock or from the glacial deposits, while the glacial gravels usually contain pebbles from many different sources. The glacial gravels have been deposited either directly from the ice, from the water resulting from the melting of the ice, or from the water and ice working in conjunction. The deposits from the ice are usually unassorted and the pebbles and boulders occur embedded in a mass of clay or sand. These deposits are not usually exploited for gravel, except where the clay is less than 30 per cent. of the mass and the fragments are under two and a half inches in diameter. The streams resulting from the melting of the ice usually assorted the drift, bringing together the pebbles in one place and the clay and sand in another. In some instances the clay and sand have been so completely removed from the gravel

that it is poorly suited for road work. A small percentage of clay assists very materially in bonding the gravel and making a hard, smooth surface. The stream and lake gravels seldom contain the desired percentage of clay, and for this reason the glacial gravels are generally preferred for road improvements. The more angular the pebbles the better is the gravel suited for paving. Gravel which is used in concrete work should be clean and the individual pebbles angular. Usually the gravel found along the present stream channels fill these requirements best.

The eastern and southern portions of Wisconsin contain inexhaustible supplies of glacial gravel in which the pebbles are mainly limestone. This gravel contains very little clay, in some places not sufficient even to make it suitable for temporary pavements. In the northern and western parts of the state, glacial and stream gravels are relatively abundant. In some places the gravels are mixed with clay in such proportions as to make them well suited for temporary pavements. In all parts of the state, except the southwestern, gravel is very plentiful, but the deposits suitable for road improvements are not abundant.

In the southwestern or non-glaciated portion of Wisconsin the gravels are either stream or residual deposits. The residual gravels occur on the tops of the ridges, usually mixed with large quantities of clay. They are mainly flint and have very irregular or angular outlines. The stream gravels are mainly the washed and reassorted residual gravels. During transportation by the streams, the clay and sand is largely removed and the fragments become somewhat rounded.

The gravel banks in this part of the state are relatively small and a much less abundant source of road materials than the deposits in other parts of the state.

The glacial and stream gravels in the northern part of the state consist mainly of pebbles of igneous rocks and are the most durable and best in the state. In several localities, in Marathon county for example, there occur very coarse grained granites, which have, in some places, been disintegrated to a depth of several feet. This disintegration has produced a fine gravel in which feldspar is a prominent constituent. This kind of gravel

is somewhat exceptional in Wisconsin, but it constitutes such an excellent material for road surfacing that it should not be overlooked.

GUMBO.

Gumbo is a rough, burned clay used almost exclusively for railroad ballast. In some localities where there are no quarries it has to some extent replaced stone as a road metal and for sidewalks. The character of the clay used for manufacturing gumbo is shown by the following analysis:*

Silica	55.0 to 65.0
Alumina	15.0 to 20.0
Combined Water	6.0 to 10.0
Iron Sesquioxide	5.0 to 7.0
Lime	1.0 to 3.0
Magnesia	0.5 to 2.0
Alkalies	2.5 to 4.0

This clay may be burned with or without kilns and at a low heat.

The clay is burnt to incipient vitrification, not enough heat being supplied to permit complete vitrification or slagging. The gumbo of commerce is a red, gravelly material varying in size from a coarse sand to a large sized walnut. It is very irregular and angular in shape, resembling porous, hard burned brick.

Gumbo is not manufactured or used in Wisconsin. In some parts of Iowa, Missouri, and Illinois, where stone is scarce, considerable quantities are used. There is an abundance of clay in some sections of Wisconsin that could be burned for this purpose, but the superiority, abundance and wide distribution of stone suitable for road metal practically precludes the possibility of gumbo ever being manufactured to any extent.

IRON.

In connection with the permanent improvement of the streets, iron is used, mainly in the shape of culverts, pipes, aprons,

*"Clay Deposits of Missouri," Vol. XI, Missouri Geological Survey, page 543, H. A. Wheeler.

catch basin covers, etc. Sewers, both storm water and house, are sometimes built out of iron pipes. Gas and water mains are almost universally iron pipes. Iron is also used to construct turnpike culverts. These, however, have proved expensive, owing to the fact that the covers must be made out of very strong wrought iron in order to sustain the heavy traffic which occasionally passes over them. Aprons covering the gutters on the approaches to sidewalks are commonly made of iron, as are also the steps which lead up to many public buildings. Guard rails and hitching posts are commonly of iron. Frequently the outer edge of the curb next to the sidewalk is protected by strips of iron fastened to its surface. In the case of cement curb, especially in places where the traffic is very heavy, this is a wise precaution. Covers to catch basins and to all other kinds of openings through pavements or sidewalks are usually of iron.

It is evident from the above, that iron is in many ways a very useful material in making permanent street improvements.

OIL.

Crude oil is used in the manufacture of asphalt and coal tar pavements. Otherwise it does not enter into the composition of any of the pavements now being constructed. Crude petroleum has been used in California and other states to settle the dust on the streets. It has also been used by some of the larger railroad companies to keep down the dust on the road bed, but the practicability of using it for this purpose has not yet been demonstrated.

SAND.

Commercial sand varies quite widely in its mineralogical composition, depending largely upon its original source. It is always a product of rock disintegration and is usually derived from sandstone. In its purest form it consists of grains of quartz, known commercially as silica, SiO_2. Sand, however, as well as all other secondary deposits, must have had its ultimate source in the igneous rocks. Quartz is one of the most perma-

nent of the rock forming minerals and it occurs as sand only as a result of disintegration.

Commercial sand often contains, besides quartz, varying percentages of calcite, dolomite, feldspar, mica, hornblende, kaolin, iron oxide and other less important minerals. Besides varying in composition sands also differ in the size and shape of their component grains.

The value of sand depends both upon its composition and upon the size and shape of its grains. Considerable quantities of calcite, dolomite, hornblende, kaolin or iron oxide are usually objectionable. These minerals are softer than quartz and are more readily disintegrated and decomposed. In the eastern and southern parts of Wisconsin, the lake, river and glacial sands usually contain considerable percentages of calcite and dolomite. In the northern part of the state feldspar, mica, kaolin and hornblende are the more common impurities in the stream, lake and glacial sands.

The chief sources of supply of sand in Wisconsin are the Potsdam and St. Peters sandstone formations and the glacial and lake deposits. The sandstone of the Potsdam and St. Peters formations is purer than that of the glacial or the recent river and lake deposits. As a rule sand occurs in abundance over the entire state, both in the glaciated and non-glaciated areas. In the northern part of the state, which is underlain by igneous rocks, sand is perhaps least abundant and most impure. However, even here the deposits are sufficiently numerous and extensive to supply most of the needs of the people.

In several localities in the state sand is manufactured by crushing hard quartz rock known as quartzite. The fine dust derived from crushing granite and rhyolite is also used in lieu of sand. The crushed quartzite sand is the purest of any that can be obtained in the state. Especially is this true of the sand which is manufactured at Wausau. Besides the purity the sharp, angular outlines of the grains increase the value of the manufactured sand.

The grains of sand in different deposits vary greatly in size.

In some they approach the size of gravel while in others the individuals are as fine as flour.

The individual grains in any bank may be poorly or well sorted. Sand which consists of grains of heterogeneous sizes naturally weighs more, bulk for bulk, than sand which consists of grains of uniform size. It is therefore desirable for most purposes that the sand should consist of grains of miscellaneous sizes, in such proportions as to give the maximum weight per cubic yard. This is sometimes attained by thoroughly mixing definite proportions of sand which has been previously sized by screening.

The sand grains may be either angular or well rounded. The sharp, angular grains as a rule give the most satisfactory results for street work and are therefore usually specified in all contracts in which sand is used. The soft sand rock of the St. Peters and Potsdam formations is in some places made up of rounded grains and in others of angular grains, the angularity of which is due to secondary enlargement. The lake sand is usually well rounded and is therefore less desirable for most purposes. The sharpest and most angular sand available is that which is manufactured out of quartzite. This sand is not only sharp and angular but it is also free from impurities. By screening this sand the different sizes can be mixed in such proportions as to give the least possible voids. By decreasing the amount of void space, the strength of the bonding material is greatly increased.

The best sand that can be used for the construction of pavements, sidewalks, gutters, etc., is one which consists of quartz and in which the grains are angular and of heterogeneous sizes. Three-fourths of the sand should be coarse and the remainder fine grained. For use as a cushion between the foundation and the wearing surface and for filling the joints of block pavements, a clean, coarse sand with the grains of uniform size is very satisfactory. Such sands are found in abundance in Wisconsin and can be bought at prices ranging from 50c to $2.00 a ton. The better grades of manufactured quartzite sand cost from $2.00 to

$5.00 per ton. Crushed granite and rhyolite cost about the same as quartzite sand.

SHELLS.

Some of the rivers of Wisconsin abound in fresh water clams. The shells from these bivalves occasionally contain pearls and most of them can be used in the manufacture of buttons. Hundreds of tons of these shells are dredged from the streams each year, searched for pearls and sold to the button factories. The button factories use only the thickest and best part of the shell and the remainder is thrown away as valueless. These shells are sufficiently hard and tough to be fairly well suited for road metal. There are a number of cities, along the Mississippi river, having button factories, that could use these shells, with profit, for improving their streets. Several towns are already using the shells for this purpose. However, instead of simply spreading the shells three or four inches deep over the middle of the street, they should be spread in courses and rolled as in the case of a macadam pavement.

The Mississippi, Wisconsin, Rock, Chippewa and Sugar rivers have up to the present been the largest producers of clam shells.

Some of the finest pavements in Florida and other southern sea coast states are built out of shells, and there is no reason why the Wisconsin shells cannot be advantageously used in the same way.

SLAG.

Slag is a scoriaceous by-product of smelters and blast furnaces. Its composition varies considerably at different plants, depending upon the nature of the ore and flux. As a rule it has a porous or semi-porous texture. Chemically it consists of varying percentages of alumina, silica, calcium carbonate and iron oxide. When the slag is drawn from the furnace it is usually either crushed or broken into small fragments with a mall or sledge. Sometimes it is broken down by pouring water from a nozzle upon the semi-fluid mass as it escapes from the furnace. This completely disintegrates the slag, transforming it into a coarse granular mass.

Slag is frequently used for paving in the same manner as crushed stone, coarse fragments being spread at the bottom and fine slag screenings at the top. There appears to be some difference in the servicability of slag roads in different parts of the state. This may be due to the method of construction but more probably to differences in the composition of the slag, on account of which it may be suitable or unsuitable for paving purposes.

Slag is sometimes moulded into paving blocks, and in this manner used for street paving. It is also used in place of cinders for foundations to granolithic or cement walks, curbs and gutters.

VITRIFIED CLAY SEWER PIPE.

As ordinarily known sewer pipe is a manufactured clay product. It would be more appropriate, however, to designate sewer pipe manufactured out of clay as "vitrified clay sewer pipe," to distinguish it from "cement sewer pipe," which is used in some parts of Wisconsin.

The composition of the clays used in two localities for the manufacture of vitrified sewer pipe is as follows:

	No. I.*	No. II.**
SiO_2	65.15	58.38
Al_2O_3	15.29	20.89
H_2O	....	7.53
Fe_2O_3	6.16	5.78
CaO	3.50	0.44
MgO	1.57	1.57
K_2O	5.17	4.68
Na_2O	....	0.34
Total	97.38	99.61

No. I is the analysis of a clay from a New York sewer pipe factory, and No. II is from an Ohio factory. They differ considerably in composition and serve to illustrate the range of com-

*"Clay Industries of New York," Ries, Albany, 1895.

**"Clay Worker," May, 1894, Orton.

position which clays may have and yet be handled in such a manner as to make first-class vitrified sewer pipe.

Sewer pipe should possess three qualities, the absence of any one of which makes the product imperfect and inferior. These qualities are (1), strength, (2) smoothness of interior and (3) imperviousness.

Sewer pipe should be strong enough to resist not only the pressure of the dirt filling deep trenches, but also that of steam rollers passing over the surface. The strength of the pipe is best obtained by placing a length on two end supports and loading it at the center. The weight required to break the pipe gives a measure of its ability to withstand vertical pressure. Mr. F. A. Barbour* found by experimenting that 2,800 pounds per running foot was, as a rule, the maximum load that a six-inch standard pipe would sustain. Further, experiments showed that an 18-inch pipe in a 9-foot trench carries a weight of about 325 pounds per square foot. Since an 18-inch standard pipe has a strength of 1,860 pounds per square foot, the factor of safety in this case is about five. The factor of safety, however, will depend upon the kind of material filling the trench. Sand and gravel, with a coefficient of friction of 0.69, will transmit 0.31 of its own weight, while wet clay with a coefficient of friction of 0.35 will transmit 0.65 of its weight to the pipe underneath.

Mr. Barbour's experiments seem to show that the load transmitted far underground by steam rollers is about the same per cent. as in the case of earth filling. Thus, if a steam roller exerts a pressure of 2,500 pounds per square foot on the surface of a clay trench, this will add 1,625 pounds per square foot to the pressure on the 18-inch pipe above referred to. The total pressure to be sustained will be 2,200 pounds per square foot. In this case a pipe of double standard strength, 2,800 pounds per square foot, is required.

A sewer pipe should not only present a smooth interior surface, to allow a free passage of the water, but it should also have a dense, hard, impervious body through which water can be trans-

*Journal of Association of Engineering Societies, December, 1897.

mitted only with great difficulty. Simple glossiness of the surface does not indicate imperviousness. The body of a clay pipe must be vitrified before being glazed.

The complete vitrification of the pipe also adds to the strength of the pipe, and it is therefore important that this condition of the pipe be not overlooked. A man who is experienced in handling vitrified sewer pipe can usually tell by striking the pipe a sharp blow whether or not it is perfect. The exterior of the pipe should be smooth and free from blisters and special care should be taken not to use sections that are cracked or broken.

The sewer pipe which is now used in Wisconsin comes mainly from Minnesota, Missouri, Indiana, Iowa and Ohio. Owing to the scarcity of suitable clay, the cost of fuel and the unfamiliarity of the people with the business, vitrified sewer pipe is not manufactured in Wisconsin. It is believed that suitable clay occurs in central Wisconsin and that if fuel and labor can be obtained at sufficiently reasonable prices, sewer pipe, as well as other vitrified wares, will eventually be manufactured.

STONE.

Stone is the most abundant, the cheapest and the most generally employed of all the materials used in street constructions. It occurs throughout the country in great variety, differing as widely in quality as asphalt, coal tar or any other of the materials previously described. Owing to the meagre knowledge which most people have of the composition and nature of stone, it is thought best at this place to dwell somewhat at length upon the characteristics of this road metal.

Ordinarily rocks are divided on the basis of origin into three main classes, igneous, sedimentary and metamorphic. The igneous rocks are those that have been formed through the solidification of molten magma. The sedimentary or aqueous rocks are formed out of gravel, sand, clay and lime (calcium carbonate), which have been derived from the land areas, deposited on the bottom of the ocean and afterwards consolidate through cementation and pressure.

The minerals of which the igneous rocks are composed have been formed by slow separation during the cooling of molten magma. Igneous rocks frequently contain ten or twelve minerals, although as a rule the major portion of the rock consists of two or three of the common species.

The sedimentary rocks have been derived from the land areas mainly through the mechanical attrition of the pre-existing rocks. The waves and currents of the ocean work over this material and distribute it on the bottom of the ocean, according to the size of the particles and their specific gravities. This method of formation gives rise to a class of rocks which have a much simpler composition than those of the igneous type.

The quality of different rocks used in street construction depends upon mineralogical composition, texture and structure. By texture is meant size, arrangement and manner of contact of the individual grains composing the rock. By structure is meant the parting planes or capacities to part which are present to a greater or less degree in every rock. By mineralogical composition is meant the minerals of which the rock is composed.

In order to make an intelligent selection of stone for different uses in street constructions, one should know the characteristics of a stone which contribute to its hardness, strength and durability. An intimate and thorough knowledge of the common rock forming minerals is very essential. The effect of various combinations of minerals and different textures and structures should be equally well known. All of these are far more serviceable than a knowledge of the chemical composition. The most satisfactory single method of determining these characteristics is by the use of the microscope.

The important rock-forming minerals and groups of minerals to be considered in this connection are quartz, calcite, dolomite, feldspar, mica, amphobile, pyroxene, chlorite, olivine, hematite, pyrite, limonite and magnetite.

Each of these minerals has peculiar physical properties, aside from its chemical composition, which distinguish it from every other known mineral. Minerals are recognized by their system of crystallization, specific gravity, hardness, color, lustre, cleavage and streak.

The manner of crystallization might be determinred by the outward form of each individual crystal, were it permitted to grow unobstructed. Minerals which constitute a part of a rock mass are seldom bounded by crystal faces. The adjacent minerals usually meet in irregular lines so that it is only occasionally that one can identify a mineral in a rock by searching for crystal faces. Crystal faces are usually wanting both in the igneous and sedimentary rocks. However, in some cases in the igneous rocks, the outlines of the crystals are well defined. In some of the rocks the individual minerals are so small that they can only be distinguished with the aid of a microscope. The outward crystal form being an expression of a definite internal structure, the crystal system to which a mineral belongs can frequently be determined with the aid of a microscope. In order to study a rock in this way thin, transparent sections must be prepared.

The hardness of a mineral is expressed by certain numbers which refer to a scale of hardness of 10 units composed of common well known minerals. This scale of hardness is as follows: 1, talc; 2, gypsum; 3, calcite; 4, fluorite; 5, apatite; 6, orthoclase; 7, quartz; 8, topaz; 9, sapphire; 10, diamond. The ability which any mineral has to scratch the numbers of this scale determines its hardness. The degree of hardness is expressed by the number of the mineral in the scale and the minerals of intermediate hardness are expressed by fractions.

The property of a mineral, by virtue of which it has a capacity to part more readily in certain directions than in others, is known as cleavage. A mineral may possess one or several cleavage directions. These may be well or poorly developed. The presence and perfection of cleavage and its relation to the different crystal faces is often a valuable means of identifying the minerals. A mineral which possesses several prominent cleavage directions can be broken into small particles much more readily than one in which cleavage planes are absent.

Minerals are also recognized by the color of the powder which they form when ground. In the case of the softer minerals this can be determined by scratching a piece of porcelain with the mineral to be identified.

The color and lustre are also important characteristics of minerals by which they can sometimes be identified.

The only physical properties of minerals which are important in a consideration of stone as a material for street constructions, are size, hardness and cleavage. These combined with the chemical composition of the mineral determines its value as a constituent of a rock which is used for street construction.

Quartz.—Quartz is a combination of two of the most abundant known elements, silicon and oxygen, united in the form of silicon dioxide ($Si\ O_2$). It is one of the hardest of the common rock-forming minerals, being 7 in the scale of hardness. It has no ready cleavage. As a rock-forming constituent, it is generally colorless, although when found alone it is frequently brown, yellow, purple, milk white or pink. As a rock-making constituent, the individuals usually have rounded, oval or irregular outlines. When occurring alone or in a crystal aggregate, quartz usually has perfect crystal faces.

Among all the common rock-forming minerals, quartz is one of the most abundant. It is very hard, and resists to a high degree all the agents of weathering. It is usually broken into small particles by disintegration but at the surface of the earth it is decomposed and taken into solution very slowly.

Calcite.—Calcite or calcium carbonate, more commonly known as lime or limestone, is composed of the elements calcium, carbon and oxygen combined as $Ca\ CO_3$. The hardness of calcite is 3. Its color as a rock-forming mineral is usually white or cloudy. Sometimes the impurities which it contains impart a brown or pink color. It has a perfect cleavage in three directions, on account of which it readily breaks into small six-sided pieces having inclined faces.

Calcite is often mistaken by inexperienced observers for quartz. The two minerals are almost identical in color but if the hardness of calcite (3) and that of quartz (7) are kept in mind, there will be little danger of confusing the two. The absence of cleavage in quartz also provides a means of distinguishing it from calcite.

Calcite is acted upon very readily by water containing sul-

phuric and carbonic acids. At or near the surface of the earth calcite is one of the least stable of the abundant rock-forming minerals. It makes up a large part of limestone rock, which will be considered later.

Dolomite.—Dolomite is composed of calcium, magnesium, carbon and oxygen. ($Ca, Mg CO_3$.) It has a hardness approaching that of calcite, being 3.5 to 4. It has as perfect a cleavage as calcite, but is acted upon less readily by dilute hydrochloric acid. Its less solubility in dilute hydrochloric acid is the usual field method of distinguishing it from calcite.

Feldspar.—The term feldspar is applied to a group of minerals containing two series, under both of which are included several species. Certain of the species differ in the elements which enter into their composition, while others differ merely in the percentage of such elements. The two series of minerals are ordinarily known by the name of their most common member as orthoclase and plagioclase. Orthoclase is composed of an admixture of potassium, aluminum, silicon and oxygen with occasionally a small percentage of sodium, $(K, Na)_2\ Al_2\ Si_6\ O_{16}$, (Hintze). Plagioclase contains sodium, calcium, aluminum, silicon and oxygen and its composition is represented by one of the following or some intermediate formula: $Na_2\ Al_2\ Si_6\ O_{16}$—$Ca_2\ Al_4\ Si_1\ O_{16}$. The two series of minerals differ in their system of crystallization as well as in their composition. The former is monoclinic and triclinic and the latter is triclinic. Orthoclase is the characteristic mineral of one of the two major groups of igneous rocks, to be hereafter described, while plagioclase is one of the characteristic minerals of a second of these groups.

The hardness of feldspar is 6 to 6.5, being surpassed among the common minerals only by quartz. The minerals of this series have two very prominent cleavages. Feldspar occurs only occasionally in the sedimentary rocks, being an important constituent mainly of the igneous and metamorphic varieties. Next to quartz feldspar is one of the most stable of the common rock-forming minerals. Its ready cleavages permit a freer passage of water in and through its entire mass than in the case of quartz. For this reason the molecules are slowly broken down,

resulting in a rearrangement and recombination of the elements, forming a variety of new minerals, among which are kaolin, quartz, chlorite, mica, epidote, zoosite and calcite. This process takes place so slowly, however, that it is scarcely worth attention in a consideration of stone used in street constructions.

Mica.—There are several varieties of mica, differing from one another either in the elements or in the percentage of elements of which they are composed. The two most important species are muscovite and biotite. The former consists of the elements, hydrogen, potassium, aluminum, silicon and oxygen, while the latter contains, in addition to the above, magnesium and iron. The hardness of muscovite is 2.5 and that of biotite 2.5 to 3. The chief distinguishing characteristic of mica is its easy and close cleavage. It has the appearance of being composed of very many exceedingly thin, glossy sheets piled one upon another. Both of the common varieties of mica decompose very slowly when exposed to the atmosphere. On account of its ready cleavage mica does not unite very strongly with the adjacent minerals of the rock of which it forms a part. It is therefore one of the first minerals to break down, mechanically, hastening the disintegration of the rock. It occurs mainly in the igneous or metamorphic rocks and to a less extent in the rocks of the sedimentary series.

Amphibole.—The mineral species to which this name is commonly applied consist mainly of magnesium, calcium, silicon, iron, manganese and oxygen, with or without aluminum. The two most common species are hornblende and actinolite. The hardness of these minerals is from 5 to 6, being very little less than that of feldspar. They have a very perfect cleavage, which is useful in distinguishing them from other minerals having other characteristics in common with them.

Amphibole is an essential constituent of many of the granites and more especially of the basic series of igneous rocks. It is also abundant in many of the schists and altered sedimentaries, both of which are included under the metamorphic series. This mineral alters very slowly to a mixture of carbonates, clay, limonite and quartz.

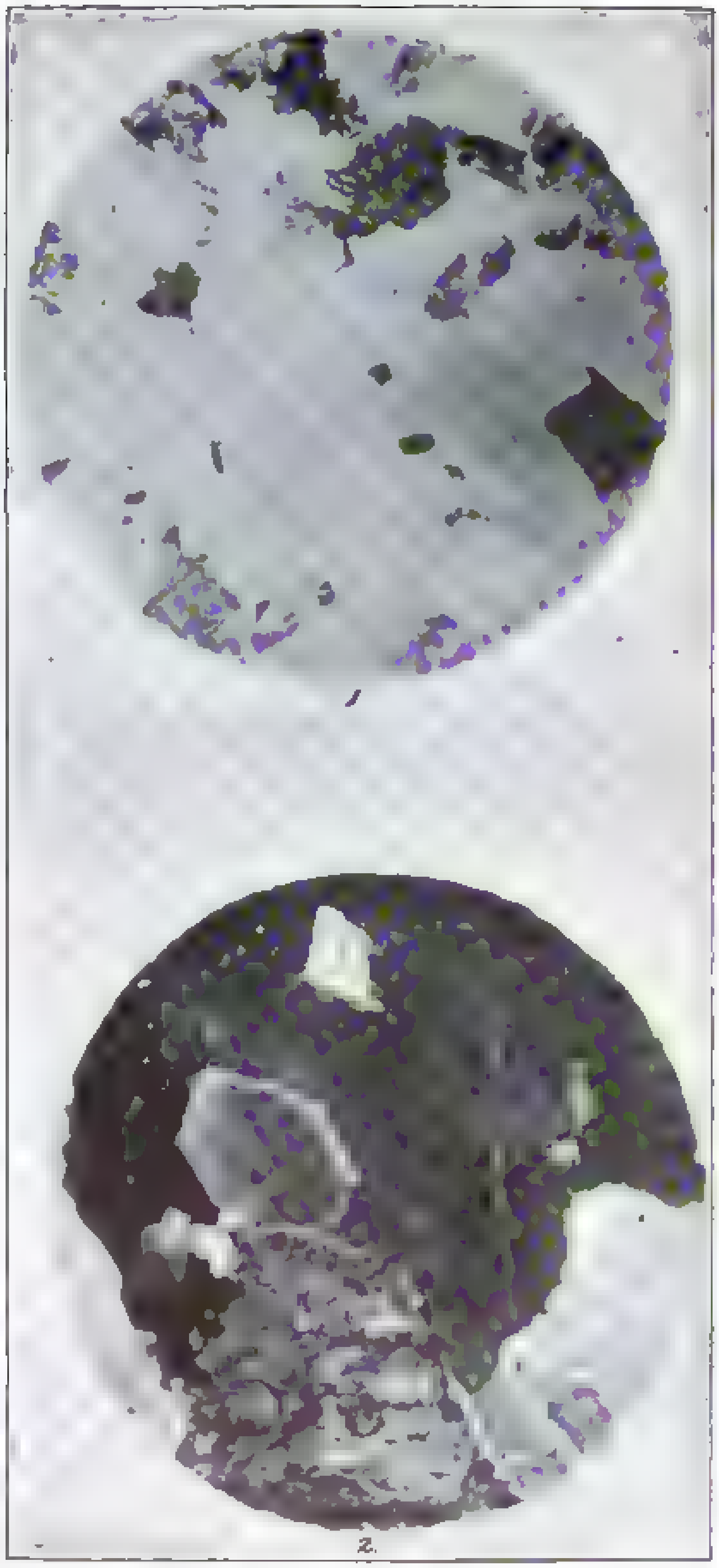
Pyroxene.—The mineral species included under the general name of pyroxene have nearly the same composition as those included in the amphibole group. The species are ordinarily composed of one or more of the elements, magnesium, calcium, iron, manganese, sodium and lithium, in combination with silicon and oxygen with the addition in certain of the important species of aluminum as an essential constituent. The hardness varies from 5 to 6, occasionally reaching as high as 7. Pyroxene has a perfect cleavage in two directions, as in the case of amphibole. The cleavage planes intersect at an angle of about 90° while in amphibole they form acute and obtuse angles. This is one of the easiest methods of distinguishing the two.

The most important rock-forming member of this group is augite. This mineral is an important constituent of many of the granite gneisses and more especially of the basic rocks. Pyroxene is slowly decomposed, altering to chlorite, calcite, iron oxide and epidote.

Chlorite.—This name applies to a group of minerals composed of various combinations and proportions of magnesium, iron, manganese, aluminum, hydrogen, silicon and oxygen. The minerals of this group are very soft, having a hardness of from 2 to 2.7. Chlorite is ordinarily an alteration product of some other mineral, but may itself be decomposed into a mixture of carbonates, clay, limonite and quartz. It is a very common constituent of the class of rocks known as "greenstone."

Olivine.—This name applies to a group of minerals differing from each other somewhat in composition but being composed in general of various proportions of magnesium, calcium, iron and manganese in combination with silicon and oxygen. The hardness of these minerals ranges from 6 to 7. Olivine decomposes readily into chlorite, talc and serpentine. It is ordinarily a constituent of the more basic igneous rocks such as diabase and gabbro.

Hematite.—Hematite is composed of iron and oxygen, the composition being represented by the formula Fe_2O_3. As a rock forming constituent, it usually occurs in small grains or as a thin film cementing together the individual grains of the sedi-



Thin Sections of Granite.

mentary rocks. It has an adhesive quality which makes it especially valuable in stone used for road construction.

Pyrite.—Pyrite is a combination of iron and sulphur ($Fe\ S_2$). It has a hardness of 6 to 6.5. It decomposes quite readily when exposed to the atmosphere, forming limonite and free sulphur or ferrous sulphate. Sometimes pyrite is an abundant constituent of both the igneous and sedimentary rocks. The readiness with which it decomposes, breaking down into iron oxide and sulphur, with the production of sulphuric acid, makes it destructive to limestones and other carbonaceous rocks in which it may occur.

Limonite.—Limonite has the same composition as hematite, with the exception that it contains water in addition to iron and oxygen. It is found, alike, in igneous, sedimentary and metamorphic rocks. It results mainly from the decomposition of other minerals rich in iron, such as pyrite. As a cementing material it is probably equally as important as hematite.

Magnetite.—Magnetite is ordinarily known as magnetic iron ore. It is composed of iron and oxygen ($Fe_3\ O_4$). It has a hardness of 5.5 to 6.5. It is a very common constituent of igneous and metamorphic rocks, being usually disseminated in the form of grains and crystals. It alters slowly to a yellowish brown limonite.

Igneous Rocks.

The igneous rocks are ordinarily composed of two or three minerals, which are the preponderant constituents, and a number of other less common minerals known as accessory constituents. There are a great many varieties of igneous rocks each having a name, but the most common are granite, rhyolite and greenstone (or trap rock).

The *granites* are those rocks which consist mainly of quartz and orthoclase with mica and hornblende as subordinate constituents.

Rhyolite is a name applied to rocks which have a fine dense ground mass in which occur large and small individuals of quartz and feldspar.

Greenstone and trap rock are names applied loosely to a class

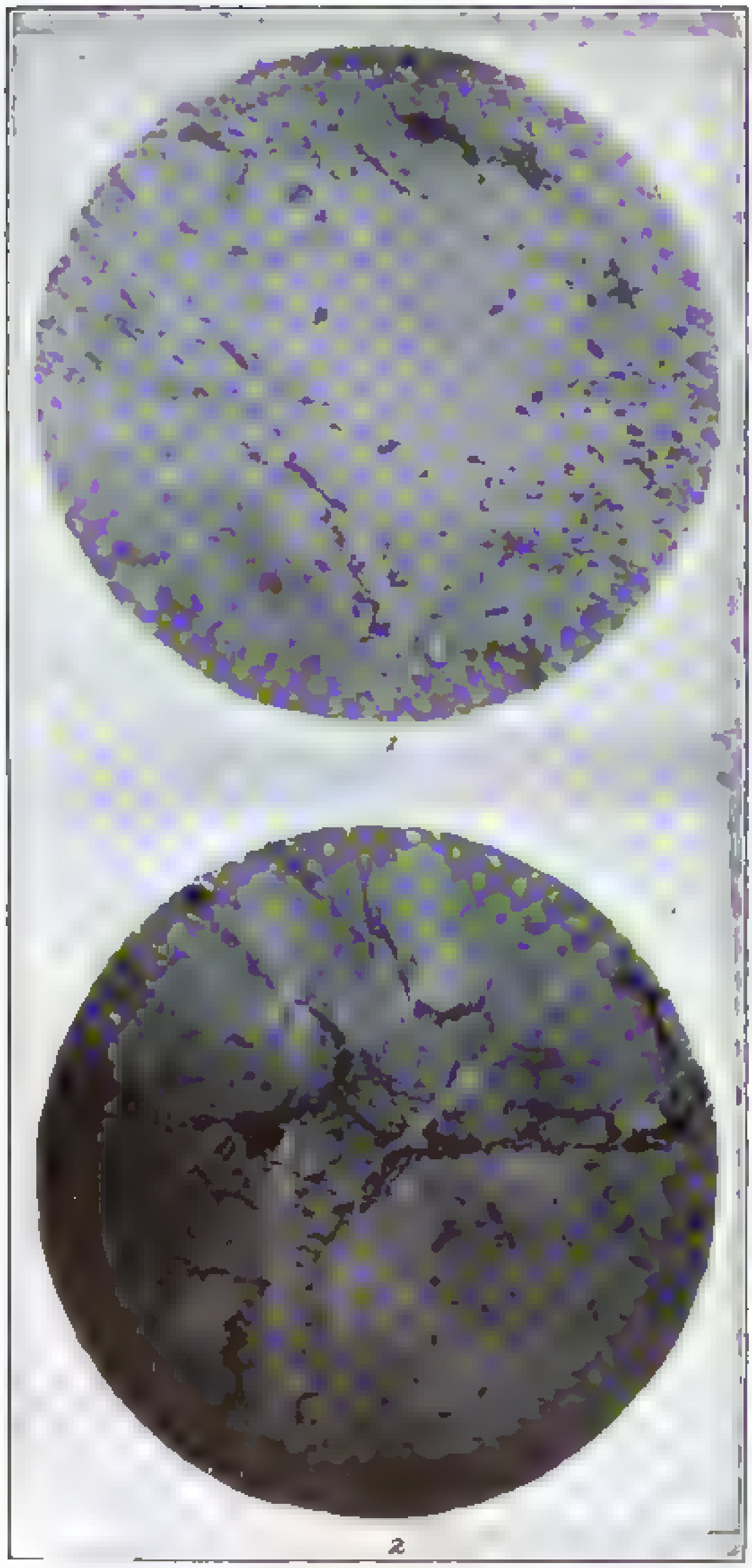
of rocks composed mainly of plagioclase, amphibole, pyroxene, olivene and mica. In some instances these rocks contain a small amount of quartz while in other cases neither quartz nor feldspar are present.

The texture of these various rocks differs with the variety. The grains may be coarse or fine and of the same or different sizes. The outlines, however, are usually irregular and the individuals interlock in an intricate manner. The manner of interlocking, however, differs in the different varieties as shown in the accompanying illustrations, Plate IV. This plate shows the texture of typical granites in which the interlocking character of the grains is well brought out. It will be observed in these illustrations that the grains are not uniform in shape, and that the individuals are held together by an irregular dovetailing along the lines of contact.

Plate V shows the texture exhibited by ordinary *rhyolites*. It will be noticed that the matrix of these rocks is very fine grained and that in it are imbedded large individuals of quartz and feldspar. In some varieties these large grains are absent and the rock is then composed entirely of a fine grained ground mass.

Plate VI shows the textures common in greenstone rocks. The reader should here observe the lath-shaped individuals in figure 1 and the manner in which they penetrate and interpenetrate one another. Figure 2, of this plate, is an example of another common texture in greenstone rocks. Here the interpenetration is not so pronounced, the texture being more like that of the granite, shown in Fig. 1, Pl. IV.

In all of these rocks it is the size of the grains and their relations to one another which largely determine their strength and durability. The peculiar interpenetration of the individuals of certain of the greenstones is the reason for their strength and durability. This also accounts very largely for the *cubical* shape of the pieces which are obtained when the stone is crushed for macadam. On an average the minerals composing the granite are harder than those comnposing the greenstone. The minerals of which the granites are composed, on the whole, have less



Thin Sections of Rhyolite.

cleavage than those of the greenstones. The individuals of the granites, as a rule, are not so complexly interlocking as those of the greenstone rocks. The products resulting from the decomposition and disintegration of the granite rocks do not furnish as strong a bond as those of the greenstone rocks. The apparently greater plasticity of the greenstone residuum accounts in part at least for its excellent bonding capacity when used for macadam.

The igneous rocks may possess certain original or secondary structures on account of which their value for road construction may be increased or lessened. These structures are known as flowage, cleavage, fissility, schistosity and jointing. The only original structure in igneous rocks is that produced by the flowage planes which result from an arrangement of the individuals of the rock with their longer axes in a common direction. On this account the rocks often have a capacity to part more readily along the flowage planes than in other directions. This arrangement of the mineral particles is usually brought about through pressure and heat after the rock has been formed. Near the surface the rocks may be actually parted into thin layers, smooth or wavy. Where such is the condition the structure is known as fissility or schistosity. Further, the rocks are everywhere broken into blocks of large or small dimensions by joints which extend in two or more directions approximately at right angles to each other. These joints may be harmful or beneficial in quarrying stone for street constructions.

However, it is not intended in this report to discuss the quarrying industry and the reader is referred to Bulletin No. IV of the reports of the Wisconsin Geological and Natural History Survey where this subject is discussed in detail.

The strength of various Wisconsin granites and their physical properties are shown in the table accompanying this chapter.

Sedimentary Rocks.

Each sedimentary rock is usually composed of one essential constituent, from which it derives its name, and several very subordinate accessory constituents. The main kinds of sed-

imentary rocks have names qualified often by the name of the most important accessory constituent. The important kinds of sedimentary rocks are conglomerate, sandstone, shale and limestone.

Conglomerate is a stone made up of roundish or sub-angular pebbles usually cemented together with clay and sand. It is a very unimportant stone in the consideration of street paving.

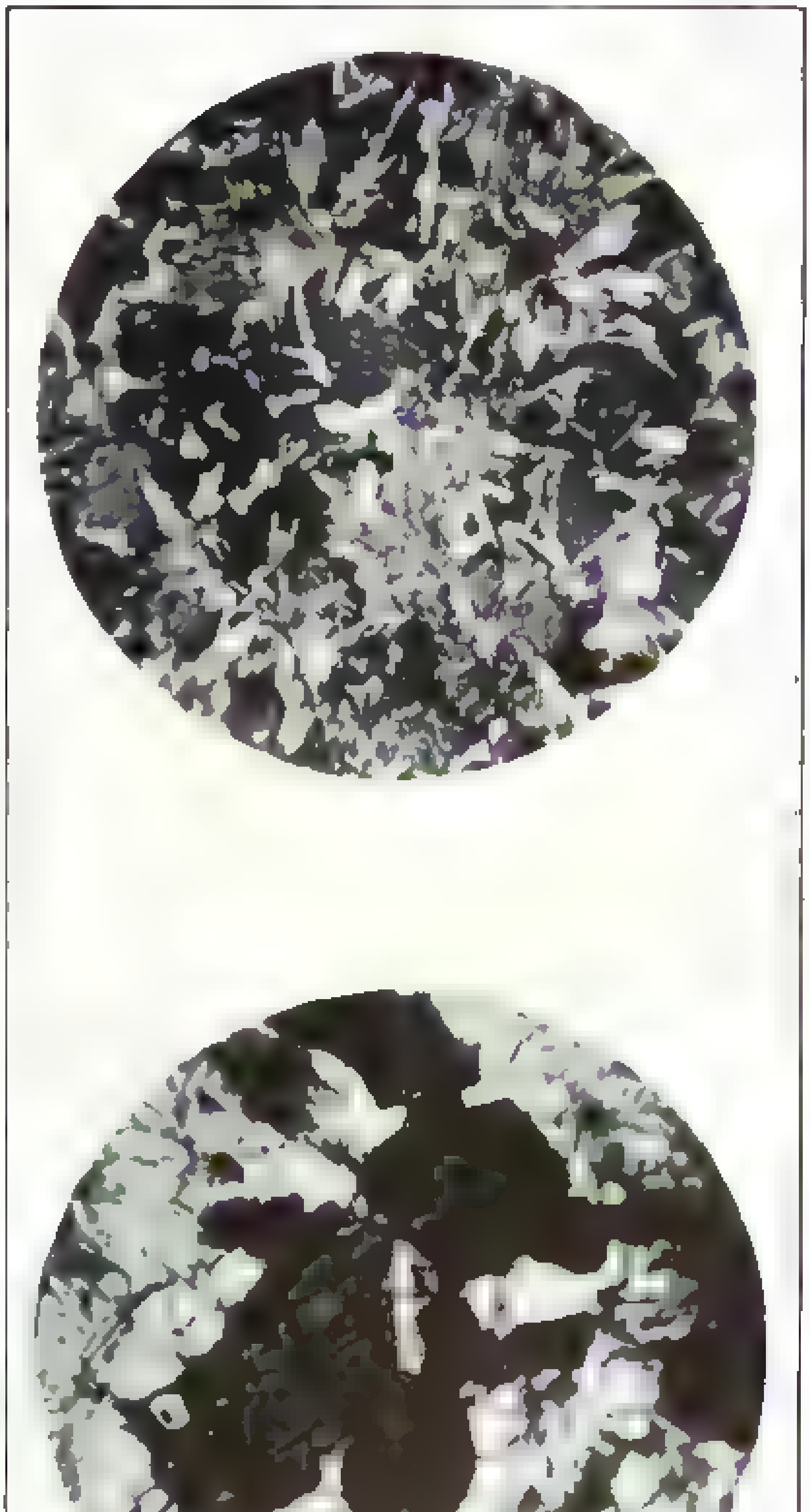
Sandstone, as the name implies, consists mainly of rounded or sub-angular grains of sand which have been cemented together with silica, calcite, iron oxide or some other accessory mineral. The induration and recementation with silica may proceed so far as to almost if not quite obliterate the shape of the original grains. The sandstone then passes into the class of metamorphic rocks and is known as a quartzite. Cementation of sandstone with silica produces one of the hardest and most durable of rocks, which, however, is brittle and often possesses a splintery fracture.

The sand grains may also be cemented with calcite in which case the stone is known as a calcareous sandstone. Such a stone is usually soft owing to the inferior adhesive or bonding capacity of calcite when associated with quartz. The cementing material of sandstone is sometimes iron oxide, which, when present in the form of hematite or limonite, adds to the strength of the stone.

Clay, mica and glauconite are frequently accessory constituents in sandstone and when present in considerable quantity have a tendency to weaken the stone.

The sandstones do not have the intricately interlocking texture exhibited by the igneous rocks. Owing to this they are softer and exhibit a very much lower crushing strength. Although they are composed of the hardest of the common minerals, their loose texture makes them one of the softest rocks.

Sandstones are used for paving blocks, curbs, sidewalks, etc., but seldom, except in the form of quartzite, do they enter into other parts of the street constructions. Each of these will be discussed later. Bedding, cleavage, fissility, and jointing may occur in these rocks the same as in the igneous rocks. Whether



Thin Sections of Greenstone or Trap Rock

or not these parting planes and capacities to part prove injurious depends upon the purpose for which the stone is to be used.

Shale is formed from mud and silt deposited in the deeper water of the ocean beyond the zone where sand accumulates. Shale is composed mainly of kaolin and quartz. Cementation and consolidation often hardens the shale until it is changed into a rock known as slate. In this form the stone is of greater commercial value. When thus altered it becomes a metamorphic rock and should receive consideration under that head. Wisconsin possesses no slate of value.

Shale occurs abundantly in some sections of the state and is used quite successfully as a temporary road metal. The shale which is very soft and plastic when broken down and wetted is valuable for surfacing sandy roads. A shale which is an admixture of clay and sand is as a rule superior to artificial mixtures for most temporary road surfaces.

Limestone consists mainly of calcium carbonate known as calcite and calcium magnesium carbonate known as dolomite. Accessory constituents such as sand, clay, bitumen, graphite, etc., are of common occurrence and give qualifying names to the limestone, such as arenaceous limestone, bituminous limestone, etc.

Limestone is one of the stones most commonly used in all street constructions in Wisconsin. This is due very largely to its wide distribution and to the ease with which it can be quarried and crushed. It is the stone which is "omnipresent" throughout the eastern and southern parts of the state.

Being composed of calcium carbonate and calcium magnesium carbonate its hardness is limited by the hardness of the mineral calcite, which is 3. Its strength is likewise limited by the strength of the minerals of which it is composed. The strength may be above that of other stones which are composed of much harder and stronger minerals, as a result of the size of the grains and the manner in which they are united to one another. Limestone differs in texture from sandstone in that the individuals are frequently more firmly cemented to one another. The texture often resembles that of an igneous rock. See Plate VIII.

Limestone is more readily acted upon by acids than most of the other rocks. Water carrying carbon dioxide and sulphuric or other acids will take calcium carbonate into solution very readily.

Limestone may possess the same structures as sandstone or shale. Bedding, cleavage, fissility and jointing may all develop under favorable conditions. The strength and physical properties of the more important Wisconsin limestones are given in the table accompanying this chapter.

Dolomite has most of the characteristics of limestone, differing mainly in being slightly harder and less soluble in dilute hydrochloric acid.

In Wisconsin most of the so-called limestones are dolomites. Dolomite would be a much more appropriate name, but the use of the term limestone has become so general that it is retained in this report.

The strength of the Wisconsin dolomites is given under the head of limestones in the table accompanying this chapter.

Metamorphic Rocks.

There are many kinds of metamorphic rocks in the north central part of Wisconsin. From the standpoint of highway construction, the quartzites, gneisses and schists are the most important. The *gneisses* and *schists* are laminated rocks which may have had either an igneous or sedimentary origin. They are distinguished by their mineralogical composition and laminated structure. They are usually intercepted by jointing planes in such numbers as to render them unsuitable for building purposes. The joints assist the quarrying of the stone and are not harmful where the stone is to be used for road construction, but the laminated structure usually makes them undesirable for macadam. They are, however, much preferable to many of the softer stones used in some sections of the state.

Quartzite was originally a sandstone, which has been hardened through a process of cementation and induration. (See Pl. IX.) Its hardness is in such marked contrast to that of the unaltered sedimentary rocks that it is frequently spoken of

Limestone Quarry John O'Laughlin Stone Co., Ives, Wis.

incorrectly as granite. The stone is usually about 95 to 99 per cent quartz (Si O_2). It is brittle and has a high crushing strength, almost equal to granite. When thoroughly cemented with silica, quartzite is one of the most durable and permanent of rocks, resisting effectually the agents both of disintegration and decomposition. When poorly cemented the stone has more the character of sandstone and is easily disintegrated.

Wisconsin is possessed of large areas of quartzite, but in no case can the stone be quarried in large blocks. The numerous joints combined with the inherent hardness of the stone make it suitable only for the manufacture of paving blocks and crushed stone. Its suitability for these purposes will be discussed in subsequent chapters.

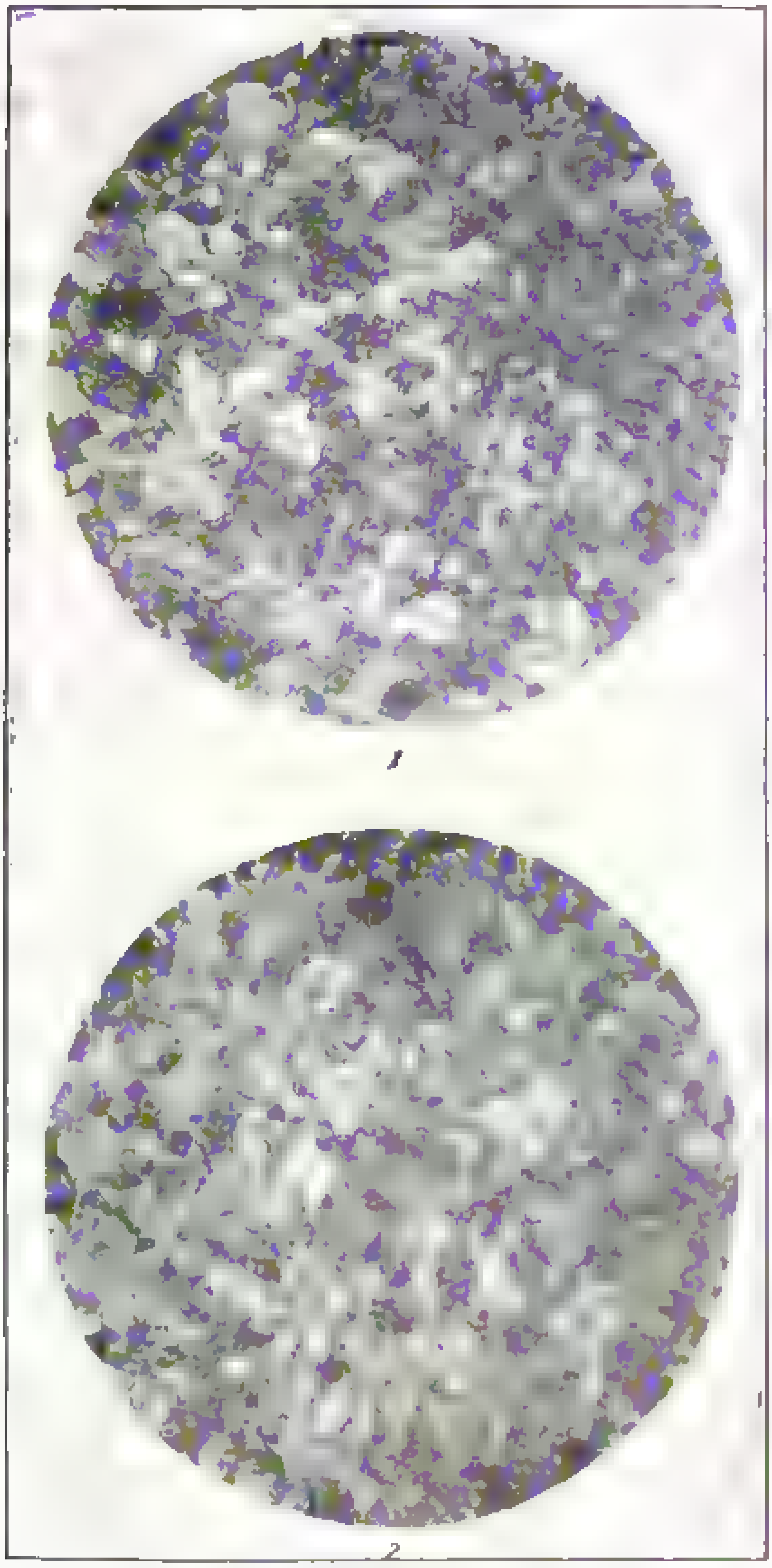
WOODEN BLOCKS.

Practically only one kind of wood,—cedar,—has been used in Wisconsin for paving purposes. In other street constructions, such as sidewalks, curbing, crosswalks, etc., most of the different varieties, including oak, pine, tamrack and hemlock, have been used. It is claimed that when used in pavements, oak becomes slippery with use and that the other kinds of wood are too soft. I believe, however, that cedar was used for paving in preference to other kinds of wood, mainly because, at that time, there was no other use to which cedar could be put. Why the blocks were made cylindrical instead of square or rectangular, no one seems to know, except that it lessened the cost. The use of blocks from five to eight inches in diameter gave the manufacturer a market for a large part of the body of the cedar tree. The size, shape and even the kind of wood used in Wisconsin and other north central states was apparently dictated by lumbermen who sought to make a market for a tree which at that time was almost valueless. There is little wonder that the people in general have become so obstinately opposed to any form of wooden block pavement after their experience with cylindrical cedar blocks.

*Crushing strength.**

Name of Quarry.	Location.	Ultimate strength in pounds per square inch.
Granite and Rhyolite.		
Amberg Granite Co	Athelstane	15,163
Amberg Granite Co.	Athelstane	23,347
Berlin Granite Co	Redgranite	24,800
E. J. Nelson Granite Co	Berlin	47,674
E. J. Nelson Granite Co	Berlin	44,009
Granite Heights Co	Granite Heights	22,060
Granite Heights Co.	Granite Heights	22,954
Milwaukee Monument Co	Redgranite	38,063
Milwaukee Monument Co	Redgranite	34,531
Montello Granite Co	Montello	43,973
Montello Granite Co	Montello	43,639
Montello Granite Co	Montello	27,132
Pike River Granite Co. (Gray granite)	Amberg	27,887
Pike River Granite Co. (Red granite)	Amberg	18,237
Limestone.		
Bauer's Quarry	Knowles.	29,189
Bauer's Quarry	Knowles	32,171
Gillen Stone Co.	Duck Creek	25,000
Gillen Stone Co.	Duck Creek	23,783
Laurie Stone Co	Sturgeon Bay	31,957
Laurie Stone Co	Sturgeon Bay	39,963
Marblehead Lime and Stone Co	Marblehead.	42,787
Marblehead Lime and Stone Co	Marblehead.	40,453
Menomonie Falls Quarry Co	Lannon	31,936
Menomonie Falls Quarry Co	Lannon	33,435
Oenning & Giesen Quarry	Fountain City.	8,830
Oenning & Giesen Quarry	Fountain City.	8,768
Story Brothers Quarry	Wauwatosa	19,111
Story Brothers Quarry	Wauwatosa	23,744
Washington Stone Co.	Sturgeon Bay	31,800
Washington Stone Co	Sturgeon Bay	31,085
Washington Stone Co.	Sturgeon Bay	30,841
Washington Stone Co.	Sturgeon Bay	35,518
Waukesha Stone Co.	Waukesha	19,234

* "Building and Ornamental Stones of Wisconsin," by E. R. Buckley, Bul. IV., Wis. Geol. and Nat. Hist. Survey, pp. 390–393.



Thin Sections of Limestone.

*Chemical Analyses of Wisconsin Building Stones.**

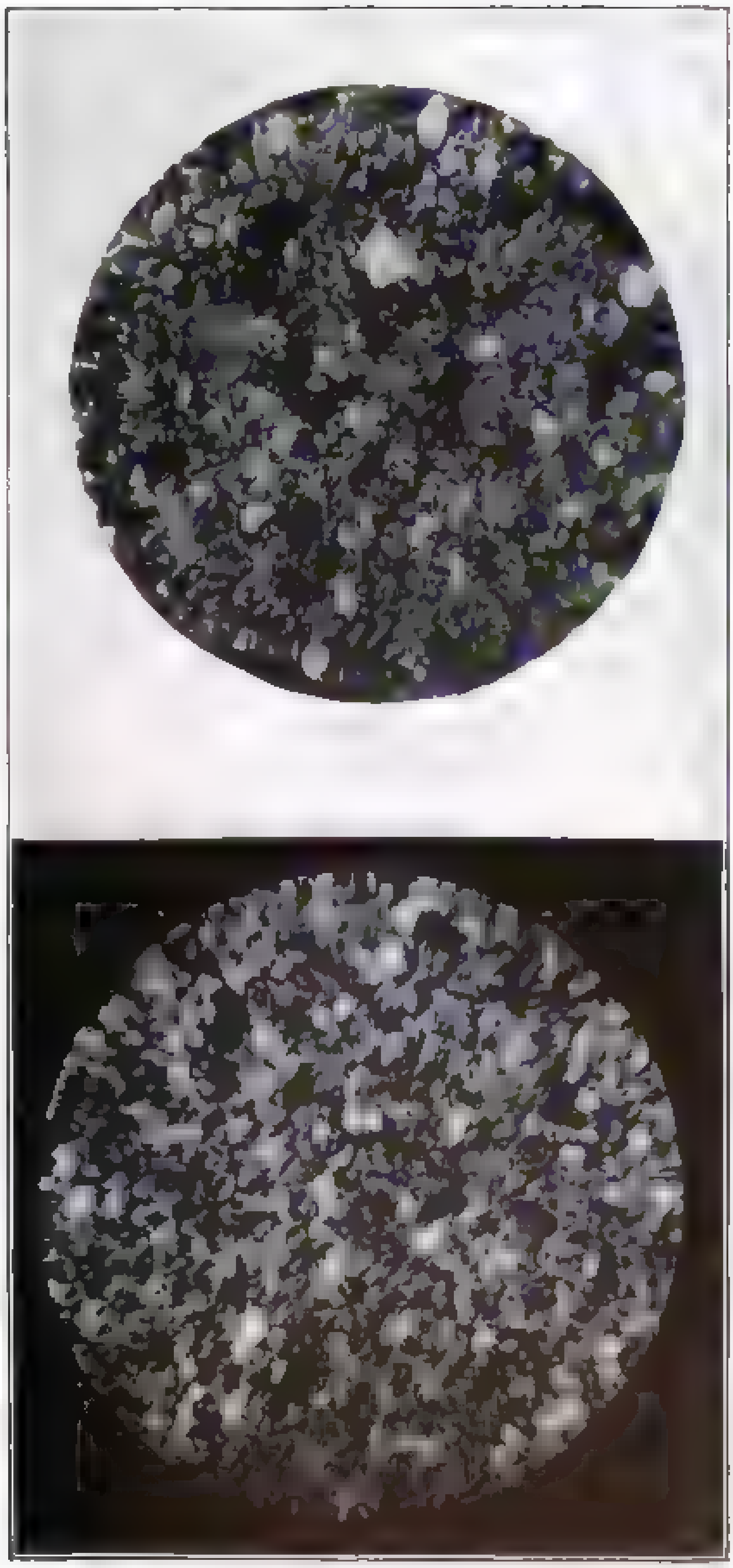
Kind of rock and Location.	SiO_2.	Al_2O_3.	Fe_2O_3.	Fe O.	Ca O.	$CaCO_3$.	Mg O.	$MgCO_3$	K_2O.	Na_2O.	Mn O.	Water.	Total.	Authority.
Granite .... (Wausau.)	76.54	13.82	1.62	....	0.85	....	0.01	....	2.31	4.32	....	0.20	99.67	W. W. Daniells.
Granite .... (Athelstane.)	68.10	20.82	1.52	2.17	1.57	....	0.95	....	3.48	2.94	....	0.54	100.09	W. W. Daniells.
Granite. .... (Montello.)	75.40	11.34	4.16	....	.90	....	....	....	6.44	1.76	....	....	100.00	F. G. Weichmann.
Granite. .... (Waushara.)	74.62	10.01	3.85	1.72	2.43	....	0.33	....	3.38	3.33	....	0.24	99.91	Samuel Weidman.
Rhyolite .... (Berlin.)	73.65	11.19	1.31	3.25	2.78	....	.51	....	1.36	3.74	....	0.44	99.23	Samuel Weidman.
Rhyolite .... (Utley.)	73.09	13.43	2.57	....	2.29	....	1.03	....	1.58	3.85	Trace.	0.71	98.56	Samuel Weidman.
Limestone .... (Duck Creek.)	3.17	1.95		....	....	49.97	....	44.58	....	....	....	....	99.67	W. W. Daniells.
Limestone .... (Genesee.)	6.32	1.02		....	....	50.96	....	41.75	....	....	....	....	100.05	W. W. Daniells.
Limestone .... (Knowles.)	0.022	0.005		....	....	54.74	....	45.07	....	....	....	....	99.837	W. W. Daniells.
Limestone .... (Marblehead.)	2.12	0.59		....	....	53.51	....	43.54	....	....	....	....	99.76	W. W. Daniells.
Limestone .... (Sturge'n Bay)	1.09	0.33		....	....	54.42	....	44.17	....	....	....	....	100.01	W. W. Daniells.

* "Building and Ornamental Stones of Wisconsin," by E. R. Buckley. Bul. IV., Wis. Geol. and Nat. Hist. Survey, p. 420.

Cedar blocks wear unevenly and their length of life depends upon the age and soundness of the tree from which they are obtained. If care were exercised in the selection of the wood; if rectangular instead of cylindrical blocks were manufactured; if a concrete foundation were used instead of boards; if the joints were grouted with cement; and if the block itself were treated with a tar-creosote mixture to make it non-absorbent, there would be very much less reason for complaint on the part of our citizens today.

Most of the wooden blocks that are now used for paving are saturated with a preparation of tar and creosote or asphalt, for the purpose of making them impervious to water. A crude coal tar mixture has been used for treating some of the blocks laid in Wisconsin, but it has not, for some reason, increased materially the life of the pavement. In some of the pavements the interspaces between the blocks were filled with a coal tar mixture, but the results were no different. Several companies are laying wooden block pavements today, claiming that they have a process of treating the blocks by which they are made impervious to water. However, experience goes to show that most wooden pavements thus far laid lose their imperviousness after four or five years' wear. When this takes place the blocks begin to swell with each rain, distorting and cracking the pavement. Decay begins and soon the blocks must be replaced with others. Nevertheless, I believe that the new wooden block is far superior to the old and is in some places the correct pavement to construct.

Logs and planks of oak, spruce, pine and other woods have been and are being used to improve sandy and marshy roads. The corduroy roads are too well known in Wisconsin to need description. This improvement consists of short logs laid crosswise of the road to prevent the horses and vehicles from sinking into the mud. The plank road was also at one time very common in eastern Wisconsin. In this construction, boards two inches thick were laid on stringers crosswise of the road. Steep slopes on sandy roads are at present frequently improved in this way.



Thin Sections of Quartzite.

Straw, brush, shavings, saw-dust, hay and cornstalks are all used more or less in the improvement of sandy and muddy roads. None of these materials are worthy of consideration.

Curbing, foundations to pavements, catch basin and all other street constructions which were formerly built out of wood, are now being constructed out of permanent materials such as brick and concrete.

The wooden blocks used for paving in most Canadian and European cities are imported from Australia and it is claimed that they are far superior to any wood which grows on the American or European continents. However, its importation for use in American cities is impracticable. The long leaved yellow pine which grows in the southern states is being used more generally for paving in the United States than any other wood.

CHAPTER III.

METHODS OF CONSTRUCTING DIFFERENT KINDS OF PAVEMENTS.

In constructing a pavement of any kind, the first consideration should be the establishment of a permanent grade, which should depend very largely upon the location of the street and the kind of traffic which it will be called upon to sustain. It should never be made to conform to the kind of pavement with which the street is to be surfaced. Rather, the kind of pavement should be made to conform to the grade of the street.

The grading of the street and the laying of sewers, water pipes, gas mains and electrical conduits should follow the establishment of the grade. Wherever excavations are made below the subgrade of the street, they should be carefully and thoroughly compacted with sand, gravel or soil which is free from organic matter. The soil used for filling the trenches should be compacted and thoroughly settled before the foundation is laid. The addition of water to the filling will very greatly assist in compacting it. Failure to observe these precautions is liable to result in damage to the pavement.

In the residence districts of a city, I do not believe that it is good taste to reduce all of the streets to a uniform level. Many of the cities of Wisconsin are built on tracts of land, the surface of which is very irregular,—consisting of hills and hollows. To reduce the highways of such cities to a level, destroys in a large measure the picturesqueness and beauty of the location. It may be more difficult to haul heavy loads over such thoroughfares and the wheelmen may be obliged to dismount and walk

up an occasional incline, but all of this is compensated for by the additional beauty which the hills contribute to the locality.

Where the topography of a city is of this hilly character, the roads should not be laid out in straight lines but should wind in graceful curves over the hills and through the hollows. A road having once been platted and the grade established, it can usually be changed only with great difficulty and sometimes at an unwarranted expense. For this reason the greatest discretion should be used in establishing street grades.

SUBGRADE.

Turning our attention to the preparation of the road bed, it should be the duty of the commissioner or engineer in charge of the construction to see that all spongy, vegetable or other objectional material is removed from the roadbed. In very soft places it is sometimes necessary to sink willows or brush wood, in order to support the filling of sand and gravel which should constitute the subgrade. The depth to which the objectionable material should be removed, depends wholly upon circumstances. Sometimes the removal of 10 or 12 inches of black muck, such as occurs in some sections of this state, will suffice when replaced by coarse sand and gravel. Where sand and gravel are not accessible, broken brick, slag, crushed stone or similar material may be substituted. The advantage gained by having sand and gravel as a sub-soil arises from its porous character by which rain water is quickly drained away from the pavement leaving it dry. Another danger to pavements from clay and vegetable soils is the expansion and contraction resulting from alternate wetting and drying. Clay often shrinks an inch and a half in a foot when dried from a semi-saturated condition. This can be observed on any brick yard or along the mud flats of the more important streams.

In every case the road bed should be thoroughly compacted before the foundation is laid. In order to insure this condition, the subgrade should be rolled with a 5 or 10 ton roller. It should be made to conform to the grade of the finished street, unless, as is sometimes the case in macadam pavements, the superstructure is made thicker at the center than at the sides.

Above the subgrade all pavements, as a rule, have two parts known as the foundation and superstructure or wearing surface. Between these two parts, in the case of block pavements, there is a third known as the cushion. Each of these will be considered separately.

FOUNDATION.

Six different materials are in common used in the construction of foundations for the different pavements. These materials are sand and gravel, wood in the form of planks, broken stone, brick, stone blocks and concrete.

Sand and Gravel.—One of the commonest and often the cheapest materials used as a foundation in the construction of pavements, is a mixture of sand and gravel. In some localities, the subsoil consists of sand and gravel and frequently the superstructure is laid directly on this subsoil which then serves as a foundation. The sand and gravel, however, in this case, constitute both the subsoil and the foundation. Wherever sand and gravel constitute the natural subsoil, they act as a coarse filter through which the water is rapidly drained away. They also form a very solid foundation upon which certain kinds of pavement, especially granite block or brick can be built with safety. Where traffic is comparatively light, as is the case in some of the smaller cities, the construction of a concrete foundation for brick or stone block pavements is often an entirely unnecessary expense. An excellent example of a brick pavement laid on a natural sand foundation, is found at Portage, Wisconsin. The principal business thoroughfares of this city have been paved with brick, no other preparation of the road bed being made except the removal of the surface soil and the grading of the sandy subsoil. This pavement shows little or no deterioration, which can be attributed to the character of the foundation, after from five to six years of use.

It would probably have been an improvement to have had the joints filled with cement grouting, thereby removing places for the possible accumulation of refuse. As it is the subsoil foundation of sand is deep and porous, offering exceptionally favorable conditions for the rapid removal of the water underground.

The introduction of five or six inches of sand and gravel to serve as a foundation on a street which has a clayey or mucky subsoil can hardly be expected to prove altogether satisfactory. A number of pavements, outside of Wisconsin, have been observed in which deterioration was apparently due to a clayey subsoil upon which a thin foundation of sand and gravel had been laid. Sand and gravel could be laid sufficiently thick to be equally as serviceable as the natural sand foundation referred to above, but the cost in this case would probably be too great to warrant its use.

The thickness of a sand and gravel foundation must depend mainly upon the character of the subsoil. A subsoil which is of such a nature as to require, under the given traffic, a foundation of over seven or eight inches of sand and gravel should be covered with a more permanent foundation.

The best gravel for foundations consists of pieces of all sizes up to two inches in diameter. A mixture of 10 per cent. sand, 10 per cent. clay and 80 per cent. gravel makes the best foundation for an ordinary subsoil. Another excellent combination consists of five inches of stream gravel, free from clay or loam, and three inches of clean, sharp sand thoroughly rolled. In case the gravel contains clay the percentage of clay should not exceed 15 or 20 per cent. Where the subsoil is clay it is better to use clean gravel and sand on the bottom.

Wooden Foundations.—In Wisconsin, wooden foundations have been used almost exclusively in the construction of cedar block pavements. They usually consist of one or two 2-inch plank laid on 2″x4″ stringers imbedded in sand or gravel. Where two thicknesses of planks are used, they are commonly laid at right angles to each other, lengthwise and crosswise of the street. When one thickness is used the plank are usually laid crosswise of the street or diagonally.

The plank foundation, as well as the cedar block pavement, has proven altogether unsatisfactory. As a result of the high price of lumber in Wisconsin, and neighboring states, its use has been almost entirely abandoned for all purposes of street construction. Where planks have been used in the past, they have

been subjected to the severest kinds of tests. The streets on which plank foundations have been used were, as a rule, poorly drained and sometimes not at all, while the cedar block surface was seldom if ever built so as to shed water. As a result of the imperfect drainage the plank and wooden blocks soon became saturated with water, mildewed and decayed. As the planks rot the blocks settle and soon the surface of the pavement becomes a succession of hummocks and hollows.

The fact that wooden foundations are no longer a possibility makes unnecessary a more extended discussion of their characteristics. They should be discarded in all parts of the country as being expensive and temporary.

Broken Stone.—Broken stone has been used very generally throughout the country as a material for foundations to all kinds of pavements. In many of the larger cities where macadam and telford pavements were constructed at an early day, stronger and more durable pavements have become necessary. These broken stone pavements, although often badly worn, are now used as foundations. Only sufficient broken stone is added to bring the street to the proper grade, after which it is surfaced with brick, stone block or whatever material may have been selected for this purpose.

The broken stone foundation differs from the concrete in that cement is used to bind the fragments in the latter, while in the former, the finely powdered stone serves this purpose. A thickness of six or eight inches of broken stone, prepared in the same manner as a macadam pavement, constitutes a very desirable foundation for pavements on all streets but those that are subjected to the heaviest kind of traffic or located in places where the subsoil is especially soft during any season of the year. A macadam foundation is, as a rule, less expensive than one constructed out of concrete. In many places where concrete is now being used, a macadam foundation would serve equally as well. The difference in the cost of the two foundations would in many instances be sufficient to pay for increasing very considerably the length of the pavement constructed.

Wherever broken stone is used as a foundation for block or

sheet pavements, care should be exercised to make the surface impervious to water. If the subsoil is properly drained and the surface of the pavement rightly constructed, broken stone ought to be as suitable as concrete for a foundation on light traffic and residential streets.

In the construction of broken stone foundations the voids between the larger pieces should be well filled with screenings. The foundation should be thoroughly compacted so that none of the pieces can move about and thus destroy their angularity. The thickness of the broken stone foundation should depend upon the nature of the subsoil and the character of the traffic.

Brick.—In the construction of brick pavements, it was formerly the practice to lay two courses of brick, one of which was the foundation and the other the surface. A brick foundation, however, is not impervious, unless the joints are filled with cement. This makes the cost of the foundation exceed that of other kinds equally as desirable. For this reason the brick foundation has been abandoned except in special cases. In some cities where brick have not worn satisfactorily they have been turned, relaid and used as the foundation for asphalt. In this position they have served very acceptably.

Stone Block.—The granite and limestone blocks which are used for street surfacing are too expensive for foundations. Occasionally, however, limestone and granite block paving which is partly worn out, is taken up, turned and relaid to serve as a foundation for a superstructure of asphalt or some other of the common pavements.

Other than this, stone blocks are only used for foundations when they form a part of telford pavements. In this case the blocks are usually of irregular size and shape.

Concrete.—The foundation which is used most universally for asphalt, brick and stone block pavements is a mixture of broken stone and cement, known as concrete. The thickness of a concrete foundation should depend upon the character of the subsoil and the nature of the traffic to which the street will be subjected after the pavement is completed. Under ordinary subsoil and traffic conditions, a thickness of five inches is suffi-

cient, although six inches is usually specified in most of the large cities of the country. The broken stone which is used may be limestone, granite, greenstone, quartzite or any other solid rock. In some cities broken vitrified brick, slag and gravel are used in place of the broken stone. In case the broken brick are thoroughly vitrified, I should consider them preferable to broken limestone for this purpose, although granite, quartzite and trap rock are the best kinds of stone that can be used. Eighty-five per cent. of the stone should consist of pieces not less than 1½ inches nor more than 2½ inches in their largest diameter. The other fifteen per cent. should consist of finer grades not larger than the interspaces between the coarser stone. The stone should be perfectly clean and free from dust and dirt.

Both portland and natural cement are used in the construction of concrete foundations. I am inclined to favor the use of portland cement, although it has been fairly well demonstrated that the natural cement is abundantly able to withstand the disintegrating conditions under which it is put when used in foundations. In specifying the kind of cement to be used, it would be good practice to follow the plan adopted by the St. Louis Board of Commissioners in the selection of vitrified paving brick. No particular brand should be specified, but any brand used by the contractor must withstand certain tests as indicated in the contract.

The cement used should be new and finely ground, at least 85 per cent. of it passing through a sieve having 10,000 meshes to the square inch. It should be capable of withstanding a tensile stress of 500 pounds per square inch, when mixed pure and made into briquettes and exposed to the air for twenty-four hours and immersed in water six days. Any cement which meets these requirements, ought to be suitable for use in concrete foundations.

As a further check on the strength of the cement, briquettes should be made out of one part by weight of cement and three parts by weight of clean, sharp sand which will pass through a sieve having 20 meshes per lineal inch and be retained by one having 30 meshes per lineal inch. These briquettes after being

exposed to the air for twenty-four hours and immersed in water six days, should have a tensile strength of 250 pounds per square inch.

All of the cement used in the construction of pavements should be tested by the street commissioner, and none should be used without his approval. No cement should be accepted that is not shipped in barrels and the contractor should be required to keep these dry until used. The commissioner should reserve the right to reject any cement which is exposed to the weather after having been tested. The street commissioner should also reserve the right to retest any of the cement once tested with the authority to reject any that may not withstand the required tests.

The concrete should be made out of seven parts of broken stone to five parts of cement mortar by volume. The mortar should consist of one part by volume of cement and four parts of clear, coarse, sharp sand, limestone, granite or quartzite screenings. The cement and sand or stone screenings should be mixed while dry until no streaks can be observed. This mixing should take place in a tight box after which sufficient water should be added to produce a mortar of proper consistency when thoroughly mixed. The mortar should be mixed fresh and if it shows evidence of beginning to set, should be rejected.

The mortar when prepared should be added immediately to the broken stone and the whole mass mixed by turning with shovels and rakes on a tight platform constructed for the purpose.

The concrete thus prepared should be placed upon the subgrade to the thickness required and compacted to a smooth surface conforming to the grade and cross section of the street. The concrete must be thoroughly compacted with iron rammers and in order to give the top of the concrete a smooth surface, it should be covered with a dressing of grout one-half inch in thickness consisting of one part of cement and four parts of sand.

No traffic should be allowed to pass over the foundation thus constructed for a period of at least twenty-four hours or until the cement has had time to set. During the period which is required for the cement to set street cars should not be allowed to use the thoroughfare.

The success of concrete as a foundation for pavements depends largely upon the use of proper cement; the care which is exercised in the use of the cement; and the removal of traffic of any kind until the cement has set. When properly constructed, there is no question but that the concrete foundation is the very best that can be obtained. The only objection which can be raised against it is the unnecessary expense which it sometimes entails.

Miscellaneous Foundation Materials.—Among the miscellaneous materials which have been used for foundations may be mentioned furnace slag and cinders. Both of these materials are used in some sections of the state for the superstructure as well as the foundation to pavements. When used for foundation purposes, they occupy about the same position with respect to the superstructure as the broken stone foundation. They are used almost universally for the foundation to the cement curb and gutter and the granolithic walk. The use of either of these materials for foundation purposes depends very largely upon their accessibility. ....

Resumè.

The heavy or light traffic streets upon which wooden block, asphalt, brick or stone block pavements are to be constructed should have either concrete or well constructed macadam foundations. For heavy traffic streets the foundation ought to be limited to concrete to insure the best possible results from the material used for surfacing. The foundation for pavements on residential streets, and in exceptional cases light traffic streets, may be sand and gravel, macadam or concrete, depending on the traffic, sub-soil and kind of pavement.

THE CUSHION.

Wherever a concrete foundation is used in the construction of a block pavement, it is customary to spread between it and the superstructure a layer of from $1\frac{1}{2}$ to 2 inches of clean sharp sand. This sand, which serves as a cushion, is only used in the construction of block pavements. Where the joints are filled with cement grouting, the cushion is in part, at least, saturated with the cement mortar poured into the joints.

In the case of sheet asphalt pavements, the sand cushion is represented by the binder course $1\frac{1}{2}$ inches in thickness. This consists of bituminous concrete composed of pieces of clean broken stone, slag or gravel, not over $1\frac{1}{2}$ inches in their largest dimension, and steam heated asphaltic cement. The asphaltic cement and broken stone, slag or gravel, are mixed in the proportion of about fifteen gallons of asphaltic cement to one cubic yard of stone.

THE SUPERSTRUCTURE.

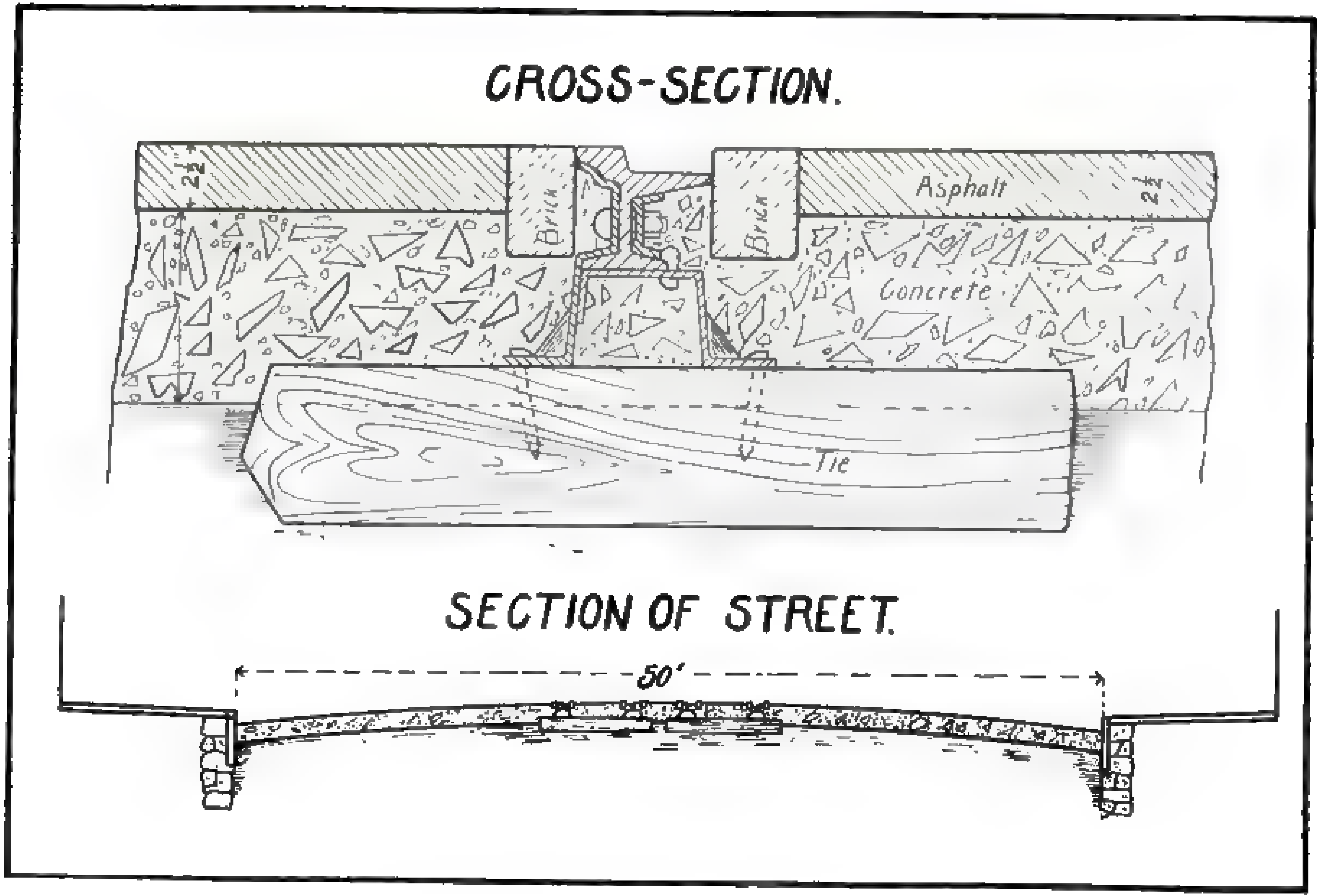
The superstructure of the modern street pavement consists as a rule of either sheet asphalt, rock asphalt, asphalt block, brick, stone block, broken stone, wooden block, tar macadam, slag, slag block, cement concrete or glass block. Among the other materials used for street surfacing may be mentioned cobble stone, gravel, cinders, plank, logs, clay, charcoal, gumbo and rubber.

*Asphalt.**—In case the street which is to be paved contains street railway tracks, the problem of constructing both the foundation and superstructure is somewhat complicated. The ties should be laid on a concrete foundation and should themselves be imbedded in concrete. Granite blocks should be laid on both sides of each rail as headers and stretchers, commonly known as "toothing stones." Experience has shown that in the

*The specifications which follow have been copied from various blank forms used in different parts of the country. A large part of the subject matter, however, has been copied from the Milwaukee specifications.

case of asphalt these blocks are necessary to protect the pavement next to the tracks. Granite blocks should also be laid around all valve boxes, manholes or other openings, and used as protection curbs at each intersection. The granite blocks used in this way are a part of the superstructure of the pavement and as such should have smooth heads and close joints,—not exceeding 3/8 of an inch in width. The upper face of the blocks should measure not less than eight inches nor more than thirteen inches in length, and not less than three and a half nor more than four and a half inches in width. The blocks should be not less than four nor more than five inches in depth. Blocks which are not uniform in texture and composition or those that vary from a rectangular shape, should be rejected. Granite blocks used in these places should be laid along with the concrete foundation and should be imbedded in cement mortar. After the cement has set, the joints should be filled to overflowing with an asphalt paving cement. This paving cement should be composed of 20 parts of refined asphalt and three parts of residual oil, obtained from the distillation of coal tar and being the residuum therefrom, mixed with 100 parts of coal tar. The coal tar, oil and asphalt should be heated and mixed in the proportions named at the place where it is needed for immediate use. This cement must be poured into the joints at a temperaature of 300 degrees Fahrenheit. Dry hot gravel not exceeding one-fourth of an inch in size, should be poured into the joints which should have been previously filled with paving cement. The same should then be consolidated by tamping with a light rammer.

After the granite blocks shall have been set, the binder course of bituminous concrete should be added on top of the concrete or macadam foundation. This bituminous concrete should consist of fine crushed limestone, granite or quartzite and asphaltic cement. The asphaltic cement should consist of 20 parts of refined asphalt and three parts of residuum oil as specified above. The stone should be heated by passing through revolving heaters and thoroughly mixed with the asphaltic cement in the proportion of about 15 gallons of asphaltic cement to one



Detailed Cross Section of Asphalt Pavement, Milwaukee.

cubic yard of crushed stone. This binder material while hot, should be spread on the foundation with iron rakes. It should be immediately rammed and rolled with hand and steam rollers while in a plastic condition until it has a uniform thickness of $1\frac{1}{2}$ inches.

Should the binder not show a proper bond by reason of having been overheated or through lack of cement or any other cause, it should be immediately removed and replaced. The upper surface of the binder course should be made parallel with the profile and grade of the finished pavement.

Upon the binder course there should be spread a wearing surface which will be $1\frac{1}{2}$ inches in thickness when completed. It should consist of 17 parts of asphaltic cement, 73 parts of sand and 10 parts of pulverized quartzite or granite. The asphaltic cement should be the same as that used for filling the joints between the granite blocks. The sand should consist of quartz and be clean, coarse and sharp. Most specifications call for 10 parts of pulverized carbonate of lime instead of quartzite or granite. It is thought, however, that the use of limestone in this connection is one of the causes of the deterioration of the pavement and its use is discouraged.

The sand and asphaltic cement should be heated separately at a temperature of about 300 degrees Fahrenheit. The pulverized granite or quartzite is usually mixed while cold with the hot sand, in the proportions indicated above. These ingredients are then thoroughly and uniformly mixed at the above mentioned temperature with the asphaltic cement.

This paving mixture should be laid upon the binder course in one coat and at a temperature of not less than 250 degrees fahrenheit. Hot iron rakes should be used in spreading the mixture. After ultimate compression, as indicated above, this layer should have a thickness of $1\frac{1}{2}$ inches. The surface should be compressed with rollers and afterwards swept with a small amount of hydraulic cement. Finally, it should be compressed with a 15 ton roller, worked both crosswise and lengthwise of the pavement. The rolling should continue until no impression is made upon the surface.

The grade of the finished street should everywhere be 1/8 to 1/4 of an inch higher than the granite blocks.

Provided granite blocks or vitrified brick are used for gutters, these should be laid at the same time that the granite blocks are laid along the car tracks and elsewhere, as indicated above. The curb and gutter will be discussed in detail in a subsequent chapter. For further discussion and illustrations covering the construction of asphalt pavements, the reader is referred to the chapter in which Milwaukee pavements are discussed.

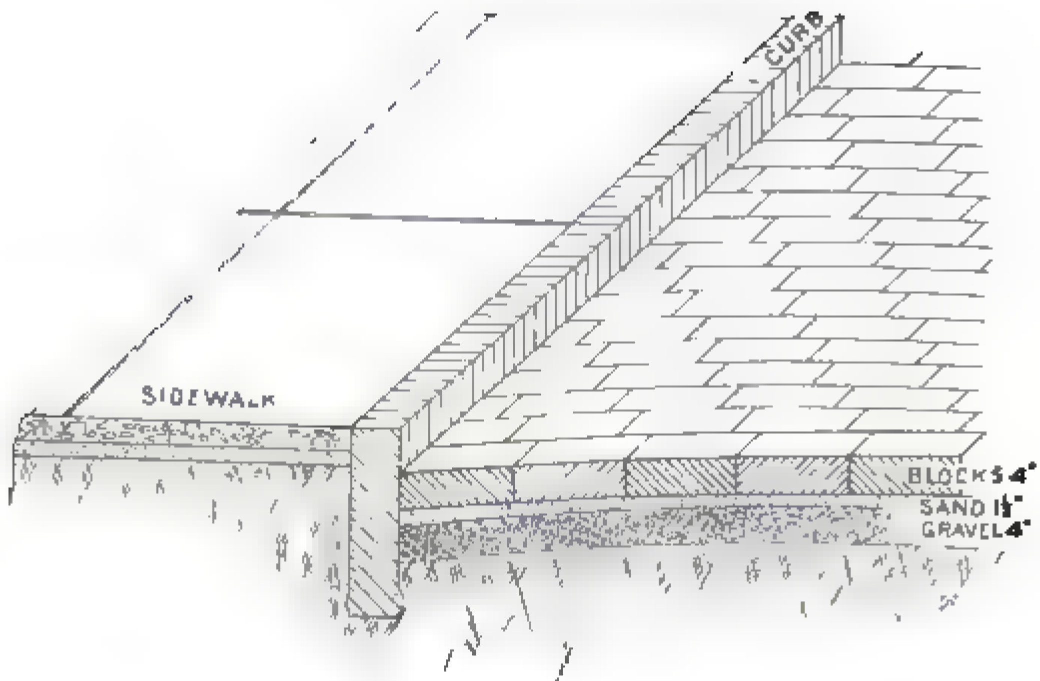
Asphalt Block.—In some of the eastern cities, among which may be mentioned New York and Washington, considerable asphalt has been used in the shape of blocks and tiles. In 1899 the Hastings Paving Company constructed nearly 350,000 square yards of this kind of pavement. It has been used only to a limited extent in Wisconsin and probably not sufficiently to warrant giving an opinion as to its value. The manufacture of these blocks was begun in 1869 but they were never considered successful until the introduction of the powerful mechanical presses in 1880 which provided a means for manufacturing a strong and durable block. For a great many years limestone was used in the asphaltic mixture, but on account of its soft character and the apparent influence which it had upon disintegration, trap and granite rock have been substituted.

In the manufacture of these blocks, an asphaltic cement composed of refined asphalt and petroleum oil, at a temperature of 300 degrees fahrenheit, are mixed mechanically with the crushed rock. This mixture is transferred to moulds having a measurement of 4" x 12" x 3" and subjected to a pressure of 120 tons. This block when completed weighs 13½ pounds. Blocks of other sizes and shapes are manufactured.

The manufacturers claim that the block is not slippery and gives forth but little sound from the horses' hoofs or wheels. The fact that the blocks are non-absorbent makes them in a high degree sanitary.

The cost of this asphalt block pavement is about the same as that of the sheet asphalt.

These blocks may be laid on any of the above described foun-



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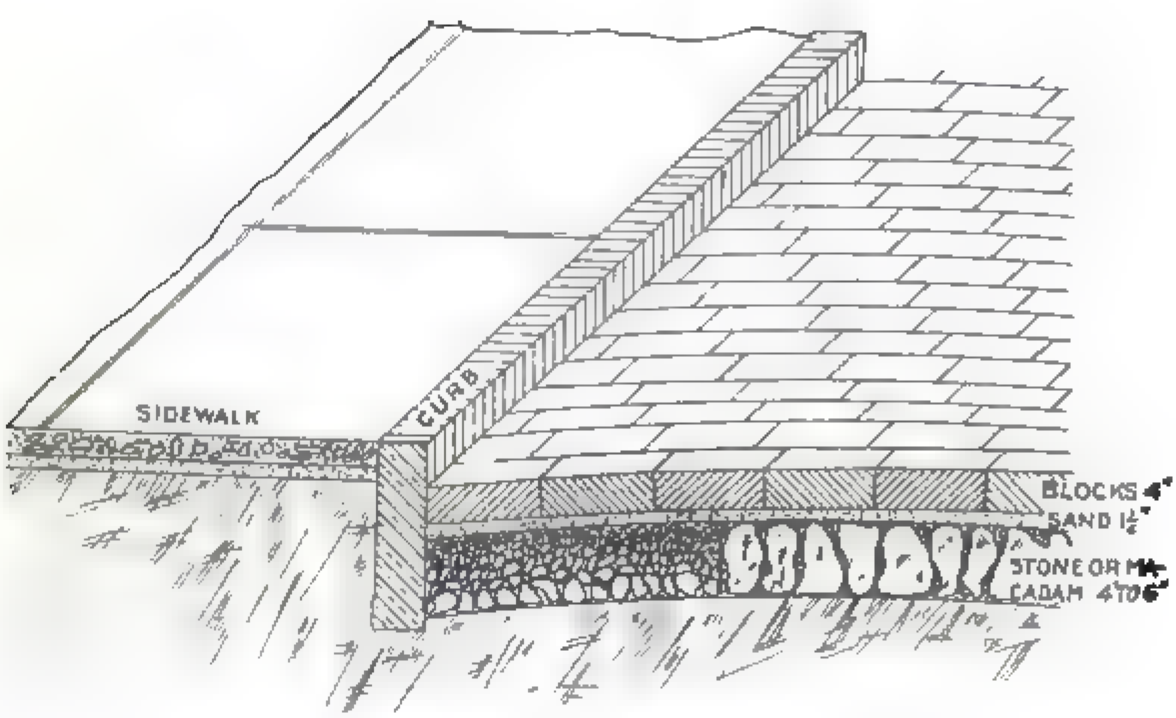
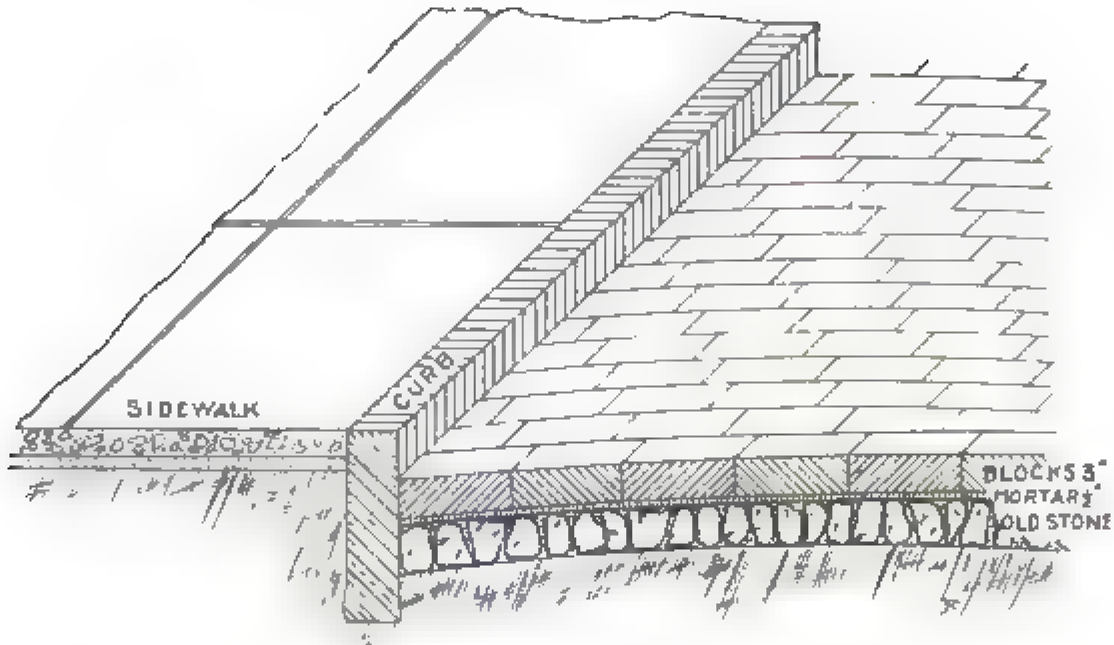


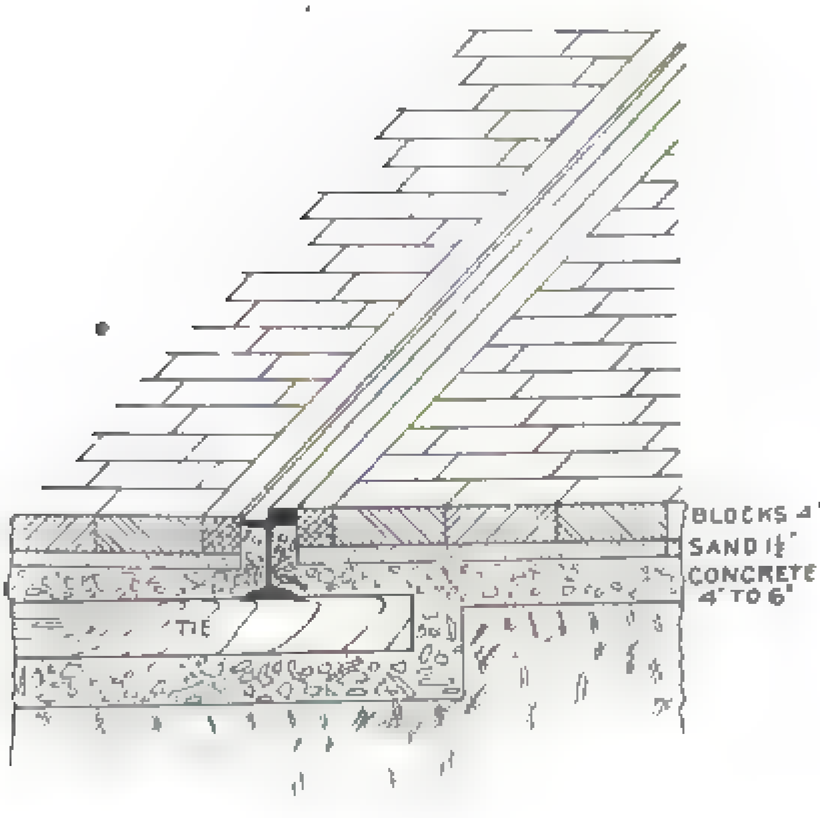
2.

Asphalt Block Pavement (Taken from circular of Hastings Pavement Co.)

1.—With gravel foundation. 2.—With macadam or telford foundation.



1.



2.

Asphalt Block Pavement. (Taken from circular of Hastings Pavement Co.)

1.—With old stone foundation. 2.—Showing method of construction with car track.

dations, concrete of course being the surest and most serviceable. When a concrete foundation is used the blocks are usually laid directly on the mortar surface. When laid on old stone block, macadam or gravel foundations, a cushion of 1½ inches of sand is used.

Natural Rock Asphalt.—As described in another chapter, natural asphalt rock consists of porous limestone or sandstone in which the interstices between the grains are filled with asphalt. A more appropriate name for such stone would be bituminous sandstone and limestone. Most contracts for natural asphalt rock pavements specify the locality from which the stone is to be obtained. For example, the St. Louis, Missouri, specifications for natural asphalt rock pavements call for Kentucky or Indian Territory bituminous sandstone. Provision is made for mixing either ten per cent of pure carbonate of lime or an equal quantity of bituminous limestone. The final mixture, however, should contain about 80 per cent of silica, not less than ten per cent of bitumen, and not over ten per cent of carbonate of lime. The bituminous limestone and bituminous sandstone should be finely ground and thoroughly mixed without the addition of any extraneous materials. The mixture should be heated in a steam heating machine at a temperature of not less than 250 degrees Fahrenheit. As in the case of sheet asphalt, the mixture should be spread at a temperature of not less than 250 degrees Fahrenheit and to such a depth that after it has received its ultimate compression, it will have a thickness of two inches. After the surface has been raked smooth, it should be rolled with a two ton steam heated roller and covered with a thin layer of hydraulic cement. Finally, the surface should be compressed with a steam roller weighing not less than five tons, until there is no impression made by the roller itself.

In view of the fact that the asphaltic sandstones and limestones differ so greatly in composition in the same localities, I am somewhat doubtful as to whether this material can ever take the place of the sheet asphalt pavement. However, in the preparation of the material for sheet asphalt pavements, so many mistakes have been made through carelessness in handling the

materials, that I do not think any very great difficulty should be experienced in constructing natural asphalt rock pavements equal to many of the sheet asphalt pavements now in use. The principle involved in the construction of natural asphalt rock pavements and sheet asphalt pavements, is the same as that involved in the manufacture of natural and portland cements. In the former the manufacturer uses the composition which is provided by nature, while in the latter, he obtains the elements separately and mixes them in proportions which experiment has demonstrated to give the best results.,

The usual specifications call for not less than ten per cent of bitumen without any reference being made to the quality. The nature of the bitumen undoubtedly influences very materially the durability of the pavement, and it is my impression that some standard should be adopted which will govern this factor.

It has been demonstrated in the pavements already constructed that more than ten per cent of calcium carbonate is injurious to the life of the pavement. A considerable percentage of asphalt rock now quarried is limestone and it is well to observe that when used alone it will have a tendency to disintegrate rapidly.

I do not anticipate that this kind of pavement will ever be used to any extent in Wisconsin. The nearest mines are in Arkansas and Indian Territory, while the nearest known deposits occur in the western part of Missouri. The cost of transportation practically precludes the possibility of constructing this pavement.

Brick.—Vitrified paving brick are now being used quite generally in Wisconsin for paving heavy and light business traffic streets. These brick are manufactured in two sizes, known respectively as "the brick" and "the block." The size of the brick is 2" or 2½" x 4" x 8"; the block size is 9¼" to 8" x 4" x 3¼" to 3⅜". Both the block and brick sizes are known in the specifications as paving brick, the desired size usually being specified in figures.

The characteristics of the best vitrified brick have been discussed in the chapter dealing with materials used in street con-

structons. The choice between large and small sized brick is mainly a matter of taste where both are properly vitrified. There is perhaps a greater probability of obtaining uniformly and thoroughly vitrified brick by specifying the smaller size. It is not uncommon for a kiln of paving brick to be over or under burned. Sometimes the fire is held a little too long or raised a little too high, on account of which the brick may be over burned and more or less warped. For fear of over burning, the fireman occasionally draws the fire before the brick are completely vitrified. Again, the kiln may be cooled too rapidly, checking the annealing. Any of these may happen at factories where the very best paving brick are now being manufactured. Owing to these circumstances by which underburned and overburned brick are sometimes produced, the manufacturer should separate his brick into three grades. No. I brick should include those which have been thoroughly vitrified and are perfect in shape; No. II, soft or underburned brick; No. III, overburned brick or those which are out of shape. Owing to the fact that brick from different kilns are often differently graded, it is very necessary that all of the brick used in paving should be subjected to a rigid examination. Where the specifications call for first grade, all overburned and underburned brick, should be scrupulously rejected. Every car load of brick received should be sampled and tested before being accepted. When the brick are removed to the street, they should be carefully piled on the sidewalk next to the curbing. It is only by observing these precautions that one can expect to obtain the best results from the brick pavement.

The sand cushion on which the brick are to be laid should be compacted and carefully spread until the surface is exactly parallel to the desired street surface after completion. This can be accomplished by using a wooden screed, the lower side of which is cut to the proper curve by computing a sufficient number of ordinates. By resting one end of the screed on top of the curve and the other end on a carefully adjusted piece of scantling on top of the rail of the street car track, an almost perfect grade can be obtained by properly weighting and drawing

it along slowly. No sand should be added to the cushion by hand, neither should the surface of the cushion be in any way disturbed during the laying of the brick.

The brick should be laid on edge, end to end, and in parallel courses at right angles to the line of the street except at street intersections, where the courses may be laid diagonally or at such other angle as may be thought proper. (See Pl. XIII.) The brick should be laid sufficiently close so that the sides and ends touch. They should break joints near the middle of the brick and should be set sufficiently high so that, after pounding and rolling, they will conform to the desired grade of the finished street. No broken brick should be used except in starting or finishing the course at the curb, catch basin, rail or other structure where it is necessary to break joints. Half bricks used for this purpose should be properly cut and fitted, and care should be exercised not to injure the brick by trimming or breaking to the proper size. It is well to specify in this connection that the work must be done by experienced men and with the aid of proper tools. Better than this, however, is the plan of purchasing half-sized brick where they can be used for these purposes. This obviates the necessity of breaking a whole brick and provides a piece of the desired size which has not been injured by hammer and chisel.

In case the brick pavement is to be laid up to the curb, thereby serving as a gutter, some advantage might be gained by laying ten or fifteen courses of brick lengthwise next to the curb. In one Wisconsin city it was found desirable to alter the cross section of the pavement in providing gutters on both sides of the street. These gutters were formed by laying ten to fifteen rows of brick lengthwise, raising half of them gradually as the curbing was approached. The construction of the gutters in this way protects the curb from the water which flows off from the surface of the street.

On each side of the pavement an expansion joint of one inch should be provided for. This joint should be filled with pitch, heated to a temperature of about 300 degrees Fahrenheit, to

within one and one-half inches of the surface, the remaining depth being filled with clean coarse sand.

After the brick have been laid, they should be rolled and tamped until the surface is smooth and conforms to the desired grade of the finished street. A roller of not less than six tons weight should be used for settling the pavement and the brick should be well tamped with a square rammer, weighing not less than 90 pounds.

Provided the traffic can be kept off of the pavement for from 24 to 48 hours, the joints should be filled either with a coal tar paving cement or portland cement grouting. Coal tar paving cement should be obtained by direct distillation of coal tar at a temperature of not less than 400 degrees Fahrenheit. It should be poured into the joints while hot and only when the brick are thoroughly dry. Special care should be taken not to pour the paving cement over the top of the brick. All the joints at the gutters, curbs, rails, catch basins, etc., should be filled in order to insure an impervious pavement.

Cement grouting may be used in place of asphalt paving cement, in which case nothing but the highest grade of portland cement should be used. This grouting should consist of one part of cement to one part of sand. The cement and sand should be thoroughly mixed and dried in portable boxes, after which sufficient water should be added to make the grout of proper consistency. Not more than an ordinary water bucket of cement should be made at one time, and this should be immediately transferred to the pavement in scoop shovels and swept rapidly into the joints with steel brooms. In order to prevent the separation of the sand and cement, the grout in the box should be constantly stirred. If this precaution is not taken, the efficiency of the grouting will be greatly lessened. *After the pavement has been grouted, it should be protected with substantial blockades to keep off the traffic. This blockade should be maintained for a period of six or seven days or until the cement has become thoroughly hardened.* Unless this precaution is observed, the cement grouting will prove extremely unsatisfactory. After the pavement is completed, it

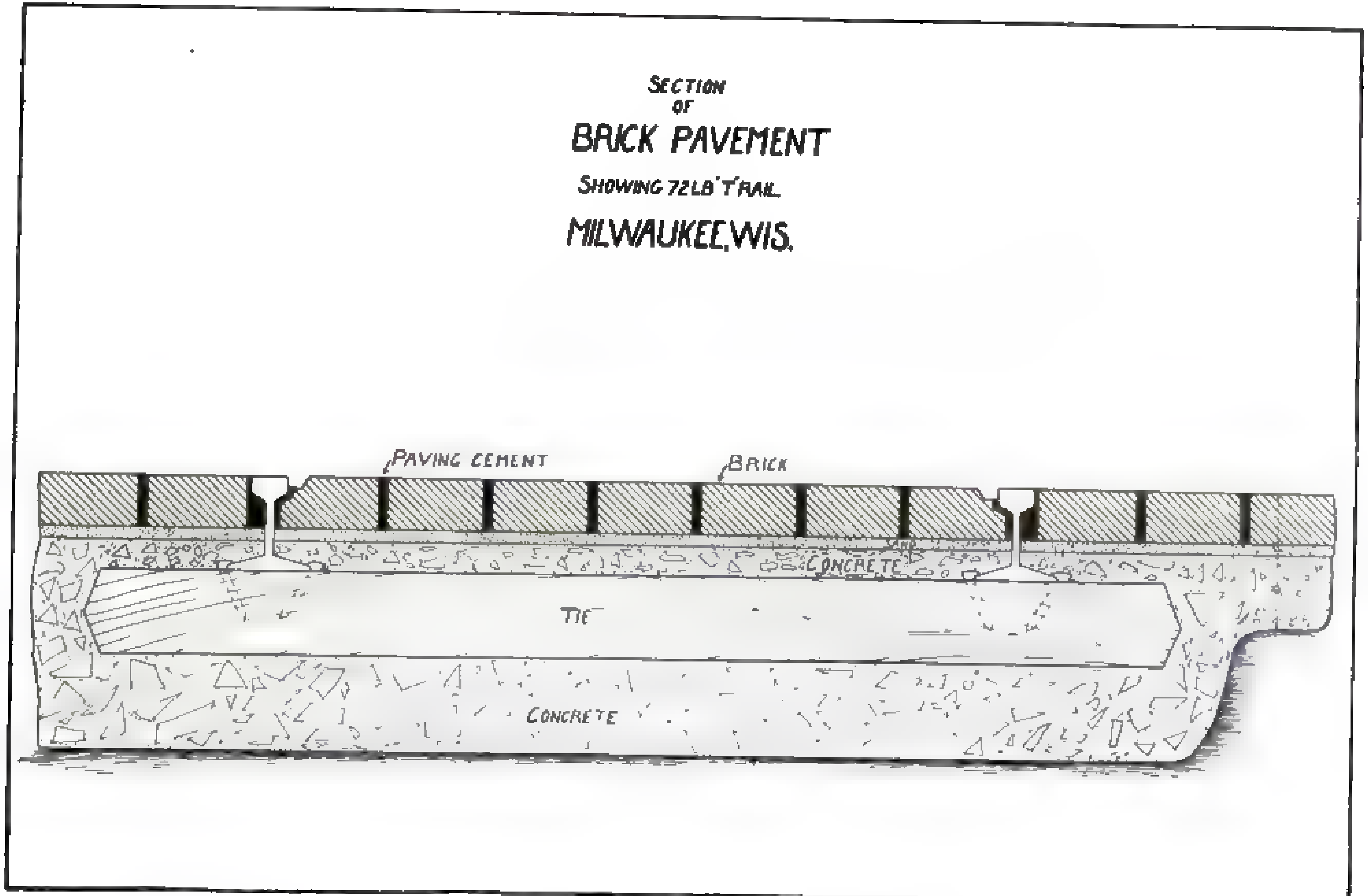
should be covered with a half an inch of clean coarse sand, to be removed at the discretion of the street commissioner or the city engineer.

In many instances neither coal tar nor portland cement grouting have been used to fill the joints of brick pavements. If one expects an ideal street pavement, he must make the surface impervious, and this can not be accomplished by filling the joints with loose sand. When the joints are filled with loose sand, they serve as places for the accumulation of filth and refuse. The sand filled joints also act as channels through which the water is drained.

Brick wear mainly through the abrasion of the surface by the traffic. It has been observed that where square cornered brick are used and not grouted with cement, they are much more liable to be chipped and broken than if grouted. If one does not plan to fill the joints with cement, brick with round corners are preferable to those with square corners. It is not possible, however, to construct as smooth a pavement with round cornered as with square cornered brick. A pavement built out of square cornered brick, in which the joints are filled with cement, gives a poorer foothold for horses than a pavement built out of round-cornered brick. This is the main reason for using round-cornered brick.

I think that it is an open question as to which is preferable, but should make my choice depend largely upon the grade of the street upon which the pavement was to be laid. If the grade is considerable, round-cornered brick should be used, while if the street is level, square-cornered brick with grouting flush with the surface are preferable.

The subject of brick pavements will be further discussed in connection with the description of pavements in different Wisconsin cities. The following is a copy of the specifications adopted by National Brick Manufacturer's Association at its sixteenth annual convention, February, 1902.



Section of Brick Pavement with T Rail, Milwaukee, Wis.

SUBSTRUCTURE OR GRADING.

Earth in excavation to be removed with plow and scraper, or other device, to within two (2) inches of subgrade, then brought to true grade with the roller, the weight of which should not be less than five (5) nor more than eight (8) tons. If the earth is too hard to receive compression through the weight of the roller, then loosen the remaining two (2) inches with a pick and cart away.

Earth in embankment must be applied in layers of eight (8) inches in thickness and each layer thoroughly rolled, and in both excavation and embankment the subgrade must have a uniform density.

If the ground is a spouty clay, tile drainage should be provided to carry off this accumulation of wet.

CURBING.

If cement is used, it should be completed; if stone, all should be hauled and distributed and set before the grading is finished, and may then be used as a guide to finish the subgrade.

It should range in thickness from four (4) to six (6) inches, twenty (20) to twenty-four (24) inches wide, the business and street traffic governing the same, and lengths not shorter than five (5) feet, except at closures. Neatly dressed on top with a square or rounded outer edge and four (4) inches down on the inside. The outer surface to be tool dressed to the depth of the face exposed and to the depth of the thickness of the brick and sand cushion. The intersection at street corners and alleys should be circular, with radius of four (4) and three (3) feet respectively.

MARGINAL CURBS.

Should always be of a hard and durable character of stone and from fourteen (14) to eighteen (18) inches deep, dressed on top and five (5) inches down on the face next to the brick.

Set to accurately fit the curvature of the cross-section of the street, on six (6) inches of concrete and backed up with the same within six (6) inches of the top.

CONCRETE FOUNDATION—CRUSHED STONE.

Should be of approved quality of hard rock, with no fragment larger than will pass through a two (2) inch ring and none smaller than will pass through a one (1) inch ring in their longest dimensions, free from all refuse and foreign matter.

SAND.

Must be clean, sharp and dry and thoroughly mixed in its dry state until the whole mass shows an even shade, with an approved brand of either hydraulic or Portland cement. If of hydraulic, the proportion of mixture should be one part of cement and two parts of sand; if of Portland cement, one part of cement and three parts of sand.

To the above mixture should be added sufficient clean water to mix to a plastic mass, and enough to rapidly subside when attempting to heap to a cone shape. To this mixture add four (4) and five (5) parts, respectively, of damp, crushed stone or clean screened gravel, and turn the whole mass over not less than three (3) times, or until every fragment is thoroughly coated with the cement mixture. For the reception of this mixture the grade should be set off in five (5) foot squares, with a stake at each corner. Tops of each should be at the surface of concrete which must be tamped until free mortar appears at the surface. Occasional sprinkling in extremely hot, dry weather is beneficial. After thirty-six hours the cushion sand may be spread.

SAND CUSHION.

Sand should be clean and free from foreign or loamy matter. It need not necessarily be sharp. It should be two (2) inches thick before the compression of the brick by rolling. The sand should be spread by the aid of a template, the whole or one-half the width of the street, made to conform with the true curvature of the street cross-section.

BRICK.

The brick should all be hauled and neatly piled inside of the curb line before the grading is finished or, if allowed by the engineer, delivered on the street in wagons and carried from the pile or wagon on pallets or with clamps, and not wheeled with barrows. They should be first-class and thoroughly vitrified, showing at least one fairly straight face, with rounded edges, with no greater radius than 3-16 of an inch. They should not be less than 2½ by 4 by 8, or more than 3¼ by 4 by 9 inches, free from cracks, with but slight lamination and at least one edge with but slight kiln marks allowed.

Such bricks or blocks shall be submitted to a test of one hour in the National Brick Manufacturers' Association standard rattler, and under the conditions prescribed by that association, and if the loss by abrasion during such test exceeds 20 per cent. of the original weight of the brick tested, then such brick or blocks shall be rejected.

BRICK LAYING.

Brick should be laid perpendicular to the curb. Broken brick or block can only be used to break joints in starting courses or in making closures. The brick shall be laid on edge, close together, in straight lines across the roadway between gutters. Gutters shall be constructed as directed by the engineer. After the brick are laid they shall be thoroughly inspected, and all warped, spalled and soft brick removed and replaced by more perfect ones, and those found with the bad face up should be turned down.

TAMPING AND ROLLING.

After the inspection is thus completed the edge of the pavement shall be tamped to grade next to the curb, to the width of six (6) or eight (8) inches out from the curb, with a hand tamper. The entire pavement shall then be rolled with a five (5) ton steam roller until all brick are thoroughly bedded and the whole surface assumes a practical plane.

EXPANSION CUSHION.

An expansion cushion must be provided for, one inch in thickness next to the curb, filled 2-3 its depth with pitch, the top 1-3 being filled with sand, and a like cushion at right angles with the street at intervals of fifty feet.

THE FILLER.

The filler shall be composed of one part each of clean, sharp sand and Portland cement. The sand should be dry. The mixture, not exceeding one-third bushel of the sand, together with a like amount of cement, shall be placed in the box and mixed dry, until the mass assumes an even and unbroken shade. Then water shall be added, forming a liquid mixture of the consistency of thin cream.

From the time the water is applied until the last drop is removed and floated into the joints of the brick pavement, the same must be kept in constant motion.

The mixture shall be removed from the box to the street surface with a scoop shovel, all the while being stirred in the box as the same is being thus emptied. The box for this purpose shall be 3½ to 4 feet long, 27 to 30 inches wide and 14 inches deep, resting on legs of different lengths, so that the mixture will readily float to the lower corner of the box, which should be from 8 to 10 inches above the pavement.

This mixture, from the moment it touches the brick, shall be thoroughly swept into all the joints. Two such boxes shall be provided in

case the street is twenty feet or less in width; exceeding twenty feet in width, three boxes should be used.

The work of filling should be thus carried forward in line until an advance of from fifteen to twenty yards has been made, when the same force and appliances shall be turned back and cover the same space again in like manner, except that the mixture for the second coating may be slightly thicker than the first.

To avoid a possibility of too great thickening at any point, there should be a man with a large sprinkling can, the head perforated with small holes, sprinkling gently the surface ahead of the sweepers. This should be done in the application of each course here specified.

After all the joints are thus filled flush with the top of the bricks and sufficient time for evaporation has taken place, so that the coating of sand will not absorb any of the mixture, one-half inch of sand shall be spread over the whole surface, and in case the work is subjected to a hot summer sun an occasional sprinkling, sufficient to dampen the sand, should be followed for two or three days.

The grouting thus finished must remain absolutely free from disturbance or traffic of any kind for a period of ten days.*

The above specifications are excellent in most particulars, appearing to be loose only in the requirements for the brick. Number one paving brick should have two straight faces and not one. In some places brick with square edges may be preferable to those with round edges. "At least one edge with but slight kiln marks" is very indefinite and leaves a loop hole by which the contractor may use over-burned brick.

The provision for expansion cushions next to the curb and at right angles with the street at intervals of fifty feet is very necessary, to provide for the expansion and contraction incident upon changes in temperature. The instructions for the use of the cement filler do not emphasize any too strongly the need of care in this part of the construction.

Macadam and Other Broken Stone Pavements.—All broken stone pavements, although they differ widely in the manner and details of their construction, are commonly known as macadam. Some of these pavements are telford, others are macadam and

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*Report of Committee on Specifications for the Construction of Brick Pavements.—Sixteenth Annual Convention of the National Brick Manufacturers' Association of the United States.—February, 1902.

Preparing the Subgrade for Macadam Pavement, Michigan Avenue, Sheboygan, Wis.

many are built on no recognized plan. However, in any case, the wearing surface is composed of broken stone which has been prepared by hand or in a crusher.

The difference between the macadam and telford pavements is entirely in the manner of constructing the foundation. In the telford pavement the foundation consists of large fragments of stone laid on edge, lengthwise of the street, with the broadest side down. Telford, the originator of this pavement, specified that "The bottom coarse or layer of stones is to be set by hand in the form of a close firm pavement. The stones set in the middle of the road are to be 7 inches in depth; at 9 feet from the center, 5 inches; at 12 feet from the center, 4 inches; at 15 feet, 3 inches." * * * "All the irregularities of the upper part of the pavement are to be broken off by the hammer and all of the interstices are to be filled with stone chips, firmly wedged or packed by hand with a light hammer so that when the whole pavement is finished, there should be a convexity of 4 inches in the breadth at 15 feet from the center."

"The middle 18 feet of the pavement is to be coated with hard stones to the depth of 6 inches. Four of these 6 inches are to be first put on and worked in by carriages and horses, care being taken to rake in the ruts until the surface becomes firm and consolidated, after which the remaining 2 inches are to be put on. The whole of this stone is to be broken into pieces as nearly cubical as possible, so that the piece in its largest dimension may pass through a ring of 2½ inches inside diameter. The paved spaces on each side of the 18 middle feet are to be coated with broken stones or well cleansed, strong gravel, up to the footpath or other boundary of the road so as to make the whole convexity of the road 6 inches from the center to the sides of it. The whole of the materials are to be covered with a binding of an inch and a half in depth of good gravel free from clay or earth."*

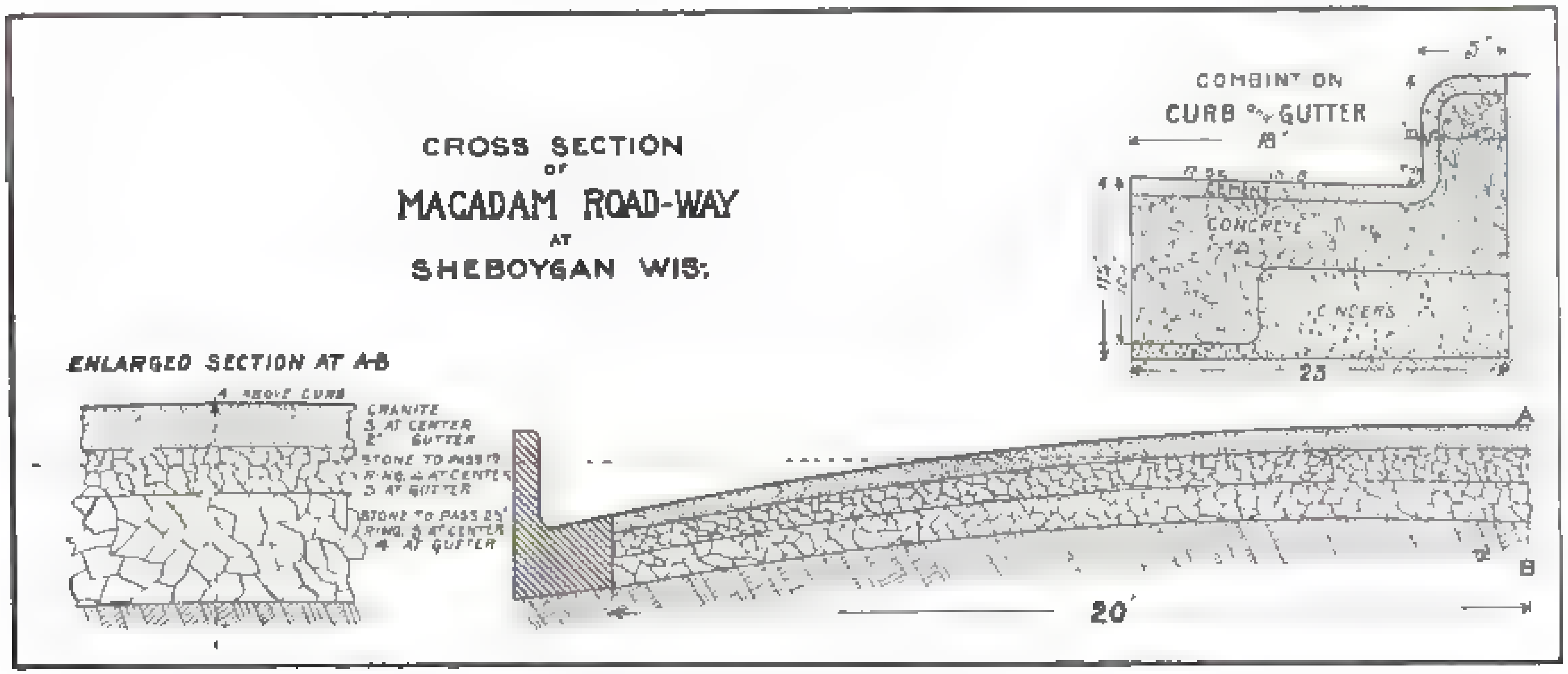
The present method of constructing telford pavements differs in some particulars from that outlined above. In the first

*Roads, Streets and Pavements, by J. Q. Gilmore.

place the subgrade is made to conform to the finished grade of the road before any stone is laid on the surface. The thickness of the stone block foundation is usually uniform from curb to curb and ordinarily does not exceed six inches. The foundation thus laid is covered with crushed stone, the pieces of which have a diameter of one and one-half to two inches. This course is laid to a thickness of from 3 to 5 inches and thoroughly rolled with a steam roller. After it has been thoroughly compacted in this maner, from 2 to 3 inches of a finer grade of crushed stone (1 to 1½ inch) is added and the interspaces filled with screenings, after which the pavement is again rolled. In general, this is the method of constructing a telford pavement. The relation of the different surface courses and the details of construction will be more fully discussed in connection with the macadam pavement. The use of large stones for the foundation to a broken stone pavement is in most places entirely unnecessary. For this reason there has been a tendency to construct this pavement only in places where the subsoil is of a soft and miry nature. The macadam and telford pavements are used together throughout the United States, the telford supplanting the macadam in such places as it may be thought necessary to construct an especially strong foundation. There are other varieties of broken stone pavements, most of which are modifications of the telford and macadam types.

Perhaps no other kind of pavement demands a more careful consideration of the materials used or a better knowledge of methods of construction than macadam. A macadam pavement in which the best materials have been used, will not wear satisfactorily unless properly constructed. Neither will a properly constructed pavement wear satisfactorily unless the best materials have been used. The kind of stone used, the thickness of the macadam, the width of the pavement,—all depend upon the nature of the subsoil, the atmospheric conditions and the amount and character of the traffic. The principle involved in constructing a macadam pavement is the same everywhere, but the details of construction often differ very greatly.

It is unnecessary to construct a macadam pavement to a



Cross Section of Macadam Pavement, Sheboygan, Wis.

thickness of two and a half or three feet as was the practice many years ago. Today, however, there are localities where macadam pavements are being constructed to a thickness of 12 or 14 inches on streets where the traffic is very light. Such a thickness is only necessary where the traffic is heavy or the subsoil very soft. In most places where a macadam pavement can be used to advantage, a thickness of eight or nine inches will be entirely satisfactory. Where the subsoil is sand or gravel, a thickness of five or six inches is often entirely sufficient. A street on which traffic is sufficiently heavy to require a macadam pavement more than ten inches thick should ordinarily be improved with a block or brick pavement and not with broken stone.

With an ordinary sand or gravel subsoil, it is a comparatively simple problem to construct a satisfactory macadam. The subsoil should be rolled until perfectly smooth and until it conforms to the shape of the proposed surface of the finished street. The subsoil should be as smooth, before the crushed rock is spread over its surface, as the surface of the macadam is when completed. If it becomes necessary to remove portions of the road bed, refilling the same with gravel and sand, this portion should be thoroughly rolled after the addition of each three or four inches of filling. Unless this is done the pavement may settle unequally after the construction has been completed.

The subsoil should be covered to a thickness of six inches with stone two to two and a half inches in diameter, after which it should be well watered and thoroughly rolled. A sprinkling of screenings over the surface before wetting and rolling is considered desirable in order to fill the interspace between the large pieces of broken stone. After thoroughly rolling this first course, a second layer three inches thick, of stone from one to one and a half inches in diameter, should be added. After spreading this course of stone evenly over the surface it should be well watered and again rolled until perfectly smooth. Upon this surface should be spread, evenly, a third course of thin screenings which should be watered and rolled as before. After this rolling has proceeded until there is no further settlement,

the pavement should be allowed to partially dry before being open to the public.

The thickness of the above courses should be varied according to the subsoil, traffic and atmospheric conditions under which any prospective pavement is to be constructed.

A macadam pavement should seldom be constructed unless the proper kind of rock is available for the wearing surface. It has been fairly well demonstrated that trap rock, rhyolite, granite and quartzite are the most suitable kinds of stone for this part of the pavement. Limestone has been used very extensively but ordinary traffic will cause it to wear so rapidly as to make the cost of maintenance much higher than it should be. In the chapter on "Materials for Road Construction," I have discussed the value of different kinds of rock for macadam, pointing out that trap rock, granite and rhyolite are the best suited for this pavement.

No city need expect to obtain the best results from macadam pavements unless the necessity for a proper system of maintenance is recognized. It is not intended that a macadam pavement should wear, without care or attention, until the only method of repairing is reconstruction. It is expected that the top dressing of two or three inches will eventually wear away, but as soon as the larger pieces of crushed rock, composing the course immediately underneath, show at the surface the pavement should be redressed with granite or other screenings. If a street is not repaired when the large fragments begin to show at the surface, the unevenness which they produce will soon wear into ruts which in time will so mutilate the road as to require it to be entirely rebuilt. From observation, one might think that the authorities in some Wisconsin cities have been constructing macadam pavements without any regard for these principles. Apparently their time has been devoted to the construction and reconstruction of macadam pavements without giving proper attention to the maintenance of those newly constructed.

There are many miles of roads and streets in Wisconsin, which are reported to have been macadamized, which have

Macadam Pavement, Process of Construction, Showing Combined Cement Curb and Gutter, Washington Avenue, Racine, Wis.

simply been covered, without rolling, with an indefinite thickness of broken stone. The construction of broken stone pavements in this manner, under the assumed name of macadam, is unfortunate, in as much as it conveys to the public a very erroneous impression of what constitutes a properly constructed macadam pavement.

Macadam pavements are objected to mainly on the ground that a great part of the time they are dusty or muddy, needing constant cleaning and repairing to keep them in reasonably good condition. It is further claimed that the cost of repairs is out of all proportion to the original cost of the pavement. In reply to this criticism, it can be said that the quantity of dust and mud depends primarily upon the kind of stone that is used and the amount and kind of traffic which passes over the pavement. For heavy business traffic streets the cost of maintaining a macadam pavement is usually so great, that other kinds of pavements are preferable. In the case of streets subjected to residential or light business traffic, a macadam pavement in which the best materials are used will ordinarily prove entirely satisfactory, if placed under a proper system of street maintenance.

Tar or Bituminous Macadam.—During the last twenty years a number of Canadian and United States cities have been constructing a pavement out of a mixture of crushed rock and coal tar, calling the pavement thus made "Tar Macadam." In 1901 Warren Brothers Company, of Boston, Massachusetts, began the construction of a bituminous macadam pavement built on principles which are the outgrowth of many years of experience with asphalt and coal tar products. The Warren bituminous macadam pavement is built along practical as well as scientific lines and gives every evidence of being a desirable pavement.

The tar macadam pavements which have been constructed in Hamilton, Toronto, and other Canadian cities have been good and poor depending upon the kind of stone and coal tar used and the conditions under which the macadam was laid. It suffices to say that a tar macadam pavement laid on Mulberry

street, Hamilton, Canada, in 1880, is in excellent condition today, and during this period has not been once repaired. The original surface which is reported to have been two inches or more thick is entirely worn away, the coarser stone now showing at the surface. Another instance where a bituminous macadam pavement has shown remarkable evidence of wear is on Chestnut street, West Newton, Massachusetts, in front of the late H. W. Warren's homestead. This pavement is said to have been laid by White Brothers in 1874, and is reported to have cost not over one-fourth of one cent per square foot for repairs.

The experiments thus far conducted, go to show that it is possible to construct a bituminous macadam pavement which is superior to other sheet pavements, at a less cost of construction and maintenance. The pavements may be constructed on a macadam or concrete foundation. In itself, it should consist of trap, quartzite or granite rock mixed with sand and coal tar in such proportions as to completely fill the voids. The coal tar adheres very tightly to the hardest rock and in this pavement should serve solely as a bonding material. In the case of the asphalt pavement, the wearing surface consists of a mixture of asphalt, gravel screenings and sand. The wearing surface of the tar macadam is composed mainly of crushed granite, quartzite or trap rock in pieces from 1 to 2 inches in diameter, the whole cemented together by coal tar. The wearing surface should be from 2 to 4 inches thick.

The difficulty in constructing this pavement is in obtaining the proper coal tar and in mixing it in correct proportions and in the right manner to give the best results.

The following extract taken from a speech by Mr. Warren before a meeting of the Massachusetts Highway Association gives very clearly and concisely the advantages claimed for this pavement:*

"The bituminous macadam pavement is a combination of the most desirable features and principles of the ordinary macadam pavement and of the asphalt pavement. Our effort is to combine the desirable

*Municipal Journal and Engineer, New York, June, 1902.

Macadam Pavement in Process of Construction. Washington Avenue, Racine, Wis.
Top dressing in piles in foreground. Finished street in the distance.

features of both, for both have very desirable features, and to overcome the weak features of both.

"We endeavor to get the foothold of macadam and to improve on the durability of asphalt, and, at the same time, to retain substantially the smoothness of the asphalt—that is the general contour of the surface. The theory on which the construction is based is that of using crushed stone of varying sizes in certain definite proportions, the sizes varying in proportion, so that the finer sizes wil fill the voids in the coarser and still finer voids, and so on from the size of a stone an inch and a half or two inches in diameter to an impalpable powder. Uniform sized stone will have voids of about 45 per cent. Ordinary sand will have voids of about 35 per cent., and the most dense sand which can be made by mixing two or more grades, will have voids of about 25 per cent. We combine the coarse and the fine particles, so that the finer will fit into the voids of the coarser, and thereby reduce the voids to 10 per cent., getting the maximum density of crushed stone. Then these materials, after heating the stone, are separated into varying sizes, and brought together in certain accurate proportions which have been previously determined upon by laboratory examination and put through a mechanical mixer with a sufficient amount of bituminous cement to thoroughly coat the particles and fill all the voids so as to make a perfectly air-tight and water-tight concrete." * * * "In general, the cost, allowing a reasonable profit, is approximately $2.00 or $2.25 a square yard, * * * about a dollar a square yard over the cost of the macadam road."

Advocates of the use of granite, trap rock and quartzite for macadam have been constantly confronted with the complaint that it is impossible to bond these kinds of stone. It is true that they do not bond as readily as limestone, but if properly handled and if a small quantity of limestone screenings or clay is used very little difficulty should be experienced. It would be better, however, if the city can afford an additional expense of one dollar a yard, to construct a bituminous macadam pavement. Experience in handling coal tar and asphalt is required, and if it is expected to obtain the best results from this pavement experienced men should be employed.

The coal tar used in this pavement must naturally always be exposed at the surface to the disintegrating effects of water and the atmosphere, in consequence of which deterioration will take place. The evaporation or oxidation of the coal tar will prob-

ably proceed faster than the stone at the surface is reduced by wear. However, by the time the coal tar is gone it may have outlived its usefulness as a bonding constituent, and such being the case, its oxidation will not be harmful to the pavement.

Glass Blocks, Scoria Blocks and Slag Blocks.—These different kinds of blocks have been used mainly in European cities and never very extensively in the United States. It is reported that glass blocks are being used to a considerable extent in Paris, France, especially on streets subjected to heavy traffic. None of these blocks have ever been used in Wisconsin and they are not considered of sufficient importance to warrant an extended discussion.

Some of the impure calcium clays which occur so abundantly in the eastern part of the state, have been used for the manufacture of glass. They contain high percentages of calcium and magnesium and moderate quantities of iron, soda and potash. It is possible that, sometime, these clays may be melted and cast in the form of glass blocks to be used for street paving. The greatest difficulty in the manufacture of glass blocks for paving would be to secure the necessary toughness. The annealing process would need to be especially adapted to the purposes for which the blocks are to be used. This is a field which is worthy of the attention of the investigator.

Granolithic and Miscellaneous Pavements.—Among the miscellaneous pavements which have been constructed in this country, may be mentioned granolithic, cobble stone, cinder, plank, log and charcoal. All of these pavements, except the first named, are of a temporary nature and their construction at present is confined almost entirely to rural or suburban districts. The cobble stone and cinder pavements are the only ones which are used to any extent in the Wisconsin cities. These, however, are being rapidly replaced by brick, stone block, asphalt and macadam.

Granolithic or cement concrete pavements have been constructed in some cities, mainly in alleys. The nature of this pavement, however, has been such as not to recommend it for general street surfacing. There is a probability, however, that

Bonding the Macadam Pavement, Michigan Avenue, Sheboygan, Wis.

sometime the apparent defects in the cement concrete pavement will be eliminated. I believe that a successful cement concrete pavement will eventually be built on somewhat the same principles as are now applied to the construction of the tar (or bituminous) macadam. Such a pavement will consist of different sizes of crushed granite, trap rock or quartzite mixed in such proportions as to give the least percentage of void space. The void space which remains will be filled with portland cement grouting in just sufficient quantity to bond the particles together. The percentage of cement, in this case, would not be great enough to cause any dangerous degree of contraction and expansion through temperature changes. The pavement might be made in squares leaving expansion joints along the curb and across the street. Such a pavement should be underlain with a sand cushion, but even then it would be more rigid than the tar macadam.

Gravel.—Of all materials used for the improvement of the highways gravel has probably been the most universally adopted. It is usually the cheapest road metal obtainable and whether a road be dusty or muddy a generous supply spread over the surface will improve very greatly the conditions. Although a muddy or sandy road may be improved by the addition of gravel such improvement is only temporary. Seldom is it possible to construct a pavement out of gravel which will be equal to macadam or any of the other pavements commonly built in the larger cities. Gravel roads are seldom suitable for heavy traffic.

The gravelled road, however, is a necessity and in itself is really a stage in the process of evolution out of which has been developed the smooth, permanent pavements of our cities. The streets of Milwaukee, for example, were first, dirt; second, gravel; third, cedar block (some of them); fourth, and at the present time, asphalt, brick, stone block and macadam. As the map of Milwaukee shows, the streets are today in all stages of this evolutionary process. Streets that were graveled several years ago are being paved today. Others that are being graveled today will be paved several years hence.

Gravel varies greatly in quality. This is due to the kind of rock, shape and size of the fragments and the percentages of clay and sand mixed with the stone. The best gravel is composed of granitic and trap rock fragments which have angular outlines and do not exceed two inches in diameter. In addition to this there should be an admixture of 10 per cent. sand and 20 per cent. clay. Out of clay similar in composition to this the New Jersey highway commission has constructed many miles of inexpensive and remarkably satisfactory pavements.

Where gravel is used it should be spread evenly over the street in courses three or four inches thick. Each course should be rolled until thoroughly packed and hard. The addition of 25 or 30 per cent. of fine crushed stone will often assist greatly in bonding the gravel. Where the gravel contains no clay, this constituent should be added and thoroughly mixed. Otherwise it will be impossible to bond the pebbles of which the gravel is usually composed.

Stone Block.—In Wisconsin four kinds of stone blocks, viz.: granite, rhyolite, quartzite and limestone, have been used in street paving. These blocks have been used in only four cities in the state, and in only one, Milwaukee, to any considerable extent. Racine, Viroqua and Fennimore, each have one or more blocks of stone block pavement. The comparative merits of granite, quartzite, rhyolite and limestone for block pavements have been discussed in a previous chapter. It suffices to say at this place, that the best stone for this purpose is a medium grained, uniform textured granite or rhyolite. In some cities, outside of Wisconsin, sandstone blocks are used for paving. Sandstone block pavements are common in Denver, Colo., and in Pittsburg and other Pennsylvania cities. Wherever limestone has been used in Wisconsin, it has proved altogether incapable of withstanding the heavy traffic for which the stone block pavement is usually constructed.

The stone used in this pavement should be free from parting planes, large flakes of mica or large crystals of feldspar. The stone should be medium grained and homogeneous, and composed of irregular, interlocking grains of the most durable min-

Limestone Macadam Pavement. Fifteenth Street, between Cedar and Wells Streets, Milwaukee, Wis.

erals. The blocks should be rectangular in form, from three and a half to four inches in width, six inches in depth and from eight to ten inches in length. They should be so dressed that the top and bottom sides are smooth. When the blocks are in place, the joints at the ends and sides should, in no case, be less than $1/8$ nor more than $3/8$ of an inch in width.

The blocks should be embedded in a sand cushion and laid lengthwise across the street, except at street intersections where they may be laid diagonally or in such other manner as the city engineer may direct. The top surface of the pavement must be made to conform with the desired crown of the street. Each course should be of uniform width and the joints should be broken by a lap of not less than three inches. All broken or chipped blocks should be removed from the pavement. After filling the joints to within two inches of the top with dry, clean gravel, the blocks should be rammed with a heavy paver's ram, to a firm and uniformly smooth surface.

After ramming, the spaces between the blocks should be completely filled with a hot paving cement obtained by the distillation of coal tar. Not less than three gallons of paving cement should be used to each square yard of the pavement. This cement should be applied to the pavement at a temperature of not less than 280° Fahrenheit. After the pitch has been introduced into the joints and while it is still hot, the blocks should be covered to a depth of not less than $3/4$ of an inch with fine, clean gravel not exceeding $3/8$ of an inch in size. Such gravel should be washed, dried and heated before being applied, in order to prevent the chilling of the cement.

In some cities it is customary to lay from five to ten rows of blocks next to the curb lengthwise of the street, to serve as a gutter. Two or three rows next to the curb are usually elevated somewhat to form a gutter, thereby keeping the water away from the curb. Expansion joints of one inch should be left on each side of the street next to the curb and at intervals of about 50 yards crosswise of the street. These joints should be filled with coal tar pitch to within one inch of the surface.

Broken blocks should be used only where it is necessary to

break joints next to the car tracks or along the line of the curb and gutter.

The joints of stone block pavements are, as a rule, filled with bituminous or asphalt cement. I believe, however, that portland cement grouting would prove more serviceable than either the coal tar or asphalt mixtures now used. Where portland cement grouting is used, it should be mixed in the proportion of one of sand to one of cement. It should be mixed in buckets holding not over a water pail of cement and be used immediately after mixing. In order to prevent the separation of the cement and sand, the mixture should be stirred constantly until poured into the joints.

The granite block pavement will be discussed more in detail in connection with the discussion of the Milwaukee street pavements.

Wooden Block.—The only kind of wooden block pavement which has been constructed in Wisconsin is the cedar block. Nearly all of the larger cities of Wisconsin are now engaged in repaving streets which were once improved with cedar blocks. It is needless to say that this kind of pavement has been unsatisfactory. The experience of the last ten years has demonstrated that the cedar block pavement as constructed in Wisconsin is expensive, dirty, unsanitary and disagreeable to ride over. After a cedar block pavement has been in use for five or six years, it is unfit for pleasure driving on account of its rough surface which causes a constant jolting of the vehicle as it passes over the pavement. The use of rubber tired vehicles reduces somewhat the jolting, but not sufficiently to justify the construction of the pavement.

The cedar block pavement has been laid, as a rule, either on a plank or sand and gravel foundation. Both of these foundations are illy adapted to this pavement and undoubtedly the deterioration of the pavement has often been hastened thereby. The cedar block pavement would unquestionably have proven more satisfactory had the foundation been concrete instead of wood. Very little cedar block pavement is being laid in Wisconsin today, but wherever it is being used the blocks are laid on

Granite Blocks with Smooth Square Heads. Bannerman's Quarry, Redgranite, Wis.

a concrete foundation. With this foundation a cushion of from 1 to 1½ inches of sand is very necessary between the concrete and the blocks.

The cedar blocks shouldd be sound, live wood, stripped of bark, six inches in length, and not less than five nor more than eight inches in diameter. They should be laid in such a manner as to make the closest pavement possible. No spaces should exist between the blocks which are more than 1½ or less than ¾ of an inch in the largest dimension. No square holes should be allowed nor should split blocks be used except next to the curb or street car tracks. The blocks should be inspected before being laid and those having decayed spots or knots should be rejected. Expansion joints should be left next to the curb to accommodate any swelling which may occur through the absorption of water.

The interspaces between the blocks should be filled with clean gravel from one half to one inch in diameter, thoroughly tamped, and the interstices filled with paving cement. The paving cement should be obtained from the direct distillation of coal tar and should be the residuum thereof. The surface of the pavement should be covered to a depth of one or one and one-half inches with fine gravel and sand.

If more attention were given to the selection of the blocks, as well as to the filling of the interspaces, so as to make the surface impervious, this pavement would prove far more serviceable than those which were constructed ten or twelve years ago.

In know of no cedar block pavement in Wisconsin in which the joints have been filled with portland cement grouting. I am inclined to believe that the use of portland cement instead of coal tar would increase very materially the durability of the cedar block pavement. However, it would have the disadvantage of being rigid, thereby resisting any expansion that might occur in the blocks.

One of the chief objections to this pavement as constructed is the heterogeneous size of the blocks. None of them are interchangeable and should a portion of the pavement be taken up to repair a service pipe it could not be relaid without refitting the

blocks. Another great objection to the wooden block pavement is its capacity to absorb water with the resultant expansion. The dangers of expansion cannot be altogether eliminated by providing expansion joints. The only method of removing this danger is by making the blocks impervious. On account of the expansion of the blocks through soaking, bituminous cement has been used in preference to all others. This cement is elastic and will give under pressure without breaking. It attaches itself securely to the wooden blocks, and any stresses which may be set up within the blocks when drying, do not easily seperate it from the block. This is the condition which exists when the bituminous cement has been properly prepared.

Attempts have been made to render wooden blocks impervious by a process called creosoting. Some of the cedar blocks used for paving the streets in Wisconsin cities have been creosoted; the results, however, have never proven satisfactory. In Oshkosh, for example, the creosoted cedar block pavements have proven very little better than the ordinary cedar block. Wooden blocks have also been treated by processes called burnettizing and kyanizing. The former consists of a treatment with chloride of zinc and the latter is a treatment with bichloride of mercury. Neither of these have been satisfactory.

The modern wooden block pavement is laid on a concrete foundation and separated from it by a sand cushion. It differs from the cedar block pavement so common in Wisconsin both in the kind of wood used and the shape of the block. The "Georgia" or "long leaved, yellow pine" is claimed to be the most durable wood thus far tried for street paving in this country. Tamrack, mesquite, cypress and juniper have also been less extensively used. The blocks are made three to four inches in depth and not less than five nor more than ten inches long. They should be sawed so that the fibre of the wood runs in the direction of the depth. The best blocks are free from sap wood, bark, decayed spots or knots. No second growth timber should be used.

Blocks which have been accepted as satisfactory should be thoroughly dried by heating them in an air tight chamber.

Limestone Block Pavement, Racine, Wis.

After the blocks are thoroughly dried and while in a vacuum of 15 to 20 inches of mercury, heavy creosote oil, specially prepared for paving purposes, should be admitted into the cylinder under a pressure of at least 60 pounds per square inch. The blocks should remain in the cylinder until they have absorbed at least 12 pounds of oil per cubic foot of timber and until the oil shall have impregnated the entire thickness of the block.

The blocks may be laid lengthwise across the street or at different angles with the curb as desired by the street commissioner or city engineer. The courses, however, should be laid parallel and the blocks driven close together. Expansion joints one inch in width should be provided at the curb line and also at intervals of 200 feet across the street. These joints should be filled with a paving mixture of tar and sand.

After the blocks have been thus laid, the joints should be filled with a paving cement composed of 15 per cent. of refined Trinidad asphalt and 85 per cent. of coal tar paving cement distilled at a temperature of not less than 600° Fahrenheit. This cement should be so prepared that it will not be brittle in cold weather nor have a tendency to run out of the joints during hot weather. The cement should be applied to the street at a temperature of from 250° to 300° Fahrenheit, and should only be used when the blocks are thoroughly dry. In this connection it has been suggested that the joints be filled to within about three inches of the surface with asphalt paving cement and that the remaining space be filled with portland cement grouting. The cement will serve to protect the asphalt from the oxidizing influence of the atmosphere, and at the same time provide a surface which will more effectually resist abrasion. In case the expansion joints are adequate to provide for the swelling and shrinking of the pavement, it may be preferable to have the joints entirely filled with portland cement grouting.

All joints should be completely filled and the surface of the pavement covered with coarse, clean sand to a thickness of 1/4 of an inch. Such of this sand as is not taken up by the blocks, should be removed later by the contractor.

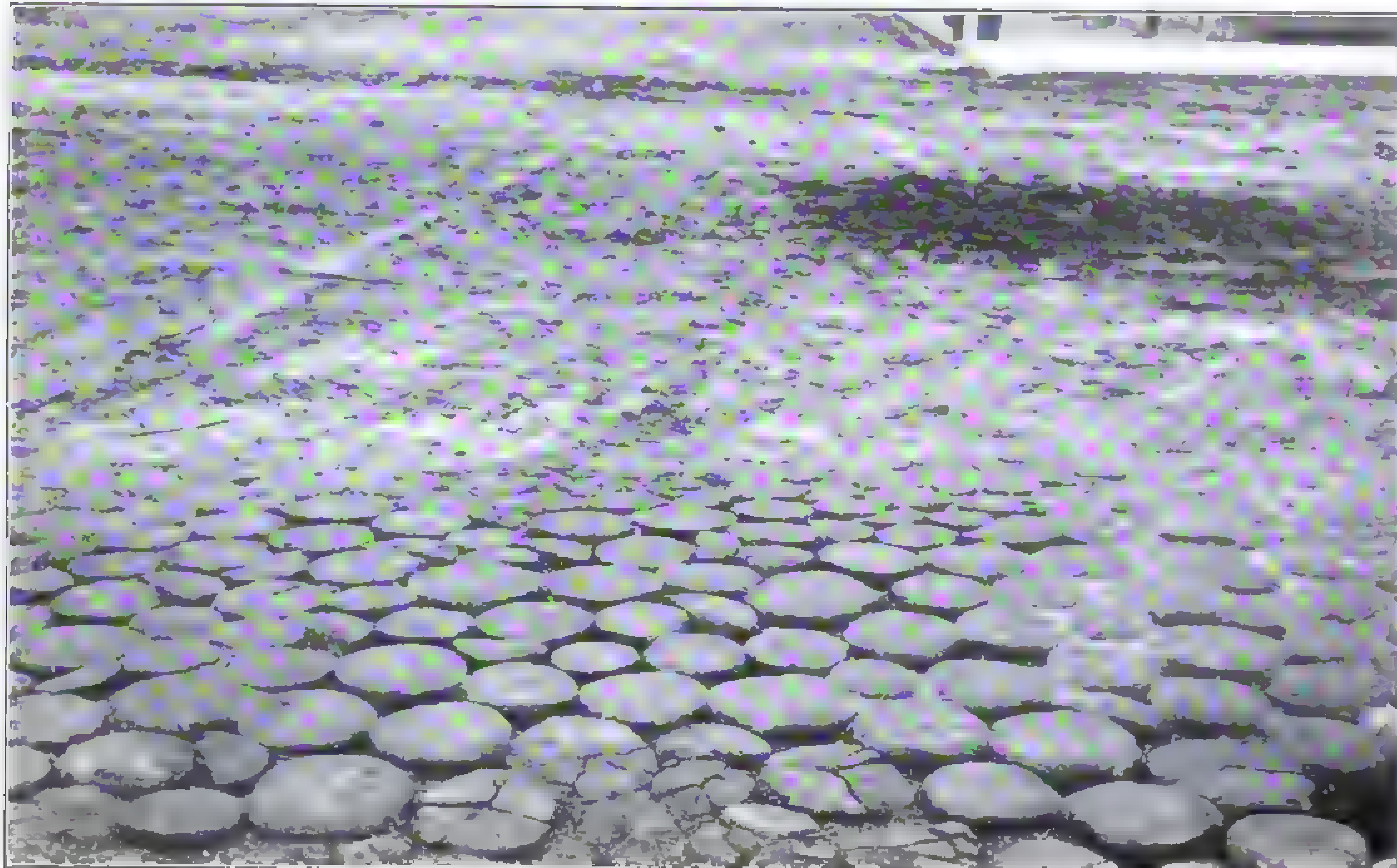
Pavements of this character have been constructed very exten-

sively in European cities and are reported to be very popular. In the United States wooden pavements of this character have been in use for only a comparatively short time. The demand, however, for a pavement which is quiet, sanitary and reduces to a minimum the cost of construction and maintenance, is increasing the popularity of the modern wood pavement. This pavement should be given more serious consideration for light business traffic and residence streets in some Wisconsin cities than is given it at the present time. I have no doubt but that the tamarack wood of Wisconsin could be so treated and used to make a pavement equal if not superior to the southern, long-leaved yellow pine.

Above all, however, it must be borne in mind that no process of treating wooden blocks has yet been devised which will render them impervious for a period longer than five or six years. The absorptive nature of the wooden block is its chief objection. The blocks of a pavement in their natural state absorb the excretions from horses; the wood becomes moist, slimy and covered, below the surface, with a growth of fungus, rendering the pavement unsanitary. The wooden pavement, when used, should be made absolutely impervious. The surface of the blocks as well as the interspaces between the blocks should be impervious.

MISCELLANEOUS STREET CONSTRUCTIONS.

Curb and Gutter.—In the construction of all pavements, with perhaps the exception of broken stone, the curb and gutter are laid before the street itself is paved. In the case of a macadam pavement, it is preferable to lay the curb and gutter after the pavement has been completed. Depending upon the materials used, the curb and gutter are either constructed separately or combined. If a stone or wood curb is constructed, it is usually separate from the gutter. The asphalt and cement gutters, however, are usually constructed on the combination plan. However, where the pavement itself serves as the gutter, a separate cement curb is usually constructed. In some instances



Type of the Cedar Block Pavement, Milwaukee, Wis.

the sidewalk and curb are connected, in which case we have a combined sidewalk and curb. This combination occurs mainly where cement concrete is used in the construction of both the curb and sidewalk.

On business streets it is impracticable to attempt to maintain park areas between the pavement and the sidewalk. For this reason, the curb and gutter are constructed next to the sidewalk, while the pavement occupies the remaining width of the street. Those pavements which are considered suitable for heavy and light business traffic streets do not, as a rule, require the construction of a gutter other than that which is formed by the laying of the pavement next to the curb. An exception to this rule should probably be made in the case of wooden block pavements. It has been shown that wooden pavements will wear rapidly through the stamping of the horses tied to the curb. The almost constant flow of water in the gutters also hastens the rate of decomposition. For this reason it is well to use the combined cement curb and gutter or brick gutter and stone curb with wooden block pavements.

Wherever brick, stone block or asphalt pavements are constructed, special gutters are usually unnecessary. As previously indicated, the curb may consist of cement, stone or vitrified clay. Which one is used, depends mainly upon the location and relative cost. If cement curb is used, it is usually constructed with a broad base tapering to three or four inches at the top. It should be built in sections as in the construction of the combined curb and gutter. The foundation should consist of from six to eight inches of cinders or sand and gravel which should be thoroughly flooded and tamped into a solid, compact mass. The base of the curb should be set at least fifteen or eighteen inches below the surface of the finished grade of the street. The top of the curb should be even with the grade of the sidewalk. The thickness of the curb both at the base and at the top, should depend upon the location of the street and the character of the traffic which it sustains.

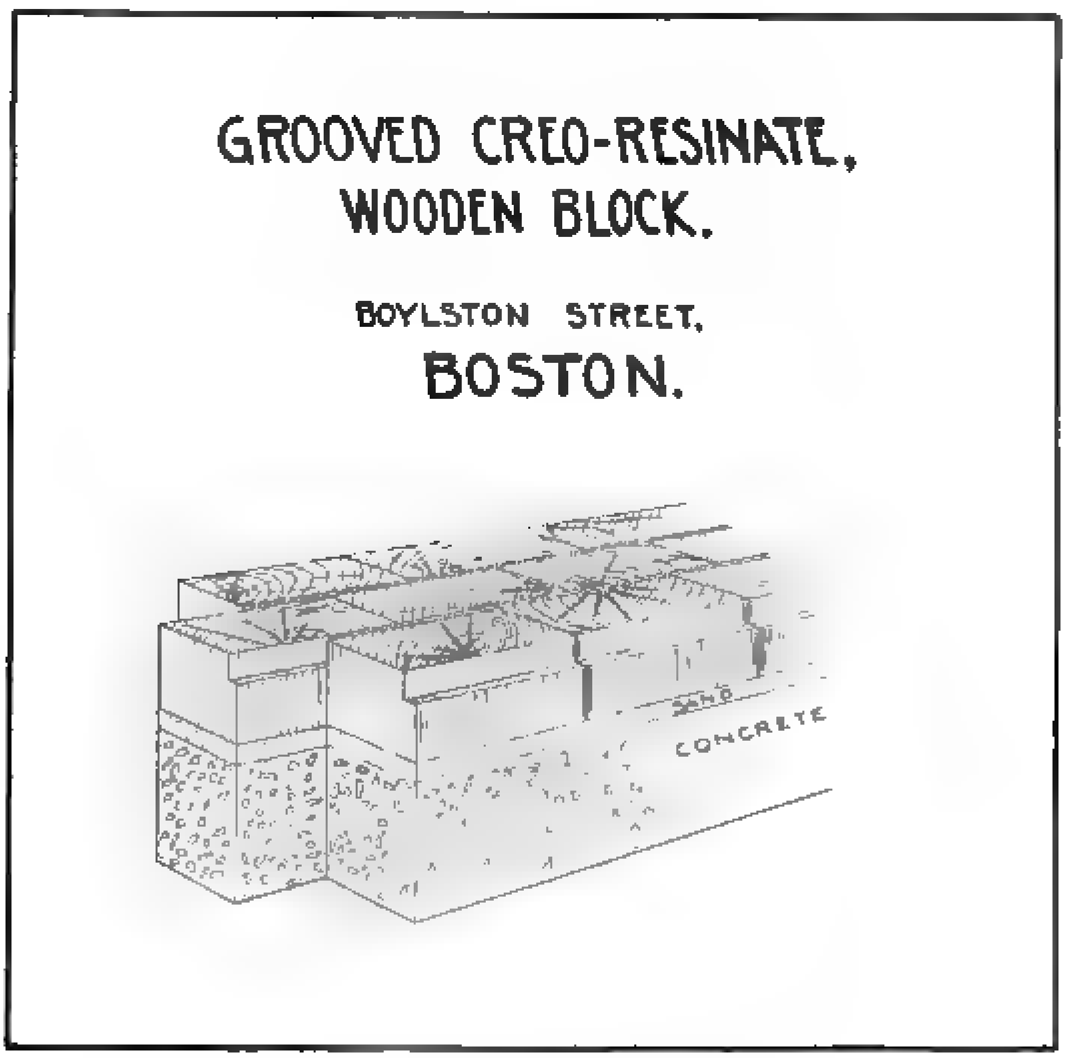
Wherever it is thought necessary to protect the curb from

moisture, drain tile should be laid underneath the foundation at a depth of six to eight inches and connected with the catch basins.

Where curbing is used without a special gutter, it is customary to use stone, although, in some of the northern and lake shore cities, wood has been substituted. Wood must necessarily be only a temporary expedient. Even though creosoted, it is unsuitable for this purpose.

Several varieties of stone have been used and are now available in Wisconsin. These varieties include granite, rhyolite, sandstone and limestone. As stated in the previous chapter on "Materials Used in Road Construction," granite and rhyolite are the most durable of any of the varieties of stone available in Wisconsin for curbing. The sandstones differ greatly in their strength and wearing capacity. In a few localities in the state, sandstone is quarried which is well suited for curbing, but there are great quantities of this stone in other sections whch is valueless for this purpose. The limestone which is quarried in different sections of the state also differs greatly in its suitability for curbing. Experience has shown, however, that the Niagara limestone, in which the quarries at Milwaukee, Waukesha and Lannon are located, is the best suited of any limestone in Wisconsin for curbing. The dimensions of the blocks used for curbing depend mainly upon the position in which they are used. Where they are placed in position to be subjected to considerable wear, they should be at least six inches in thickness and have a depth of not less than six inches below the finished sub-grade of the street. The slabs should be at least three feet long. That part of the curb which is above the level of the street should be truly squared and dressed so that when the different lengths are laid, one against the other, the joints will not exceed one-eighth of an inch. The back of the curb stone should be dressed smooth and even to a depth of at least three inches, depending upon the thickness of the adjacent sidewalk.

In selecting curbing, special care should be taken to avoid lengths which show bedding plans or other evidences of lamina-



(Taken from "Modern Wood Pavements" by Frederic A. Kummer.)

tion. Stone having incipient joints, clay seams or nodules should be positively refused.

The corners of streets, driveways or alleys should be provided with circular curb stones of the same material and dressed similar to the straight curb but cut to such a radius as may be directed by the engineer. The corner curbs should consist of one piece of stone.

Concrete, prepared similar to that used for the foundation to brick and other pavements, should be used as a foundation for all stone curbing. This concrete foundation should be six inches deep and have a breadth of twelve inches. The curb stone should not be put in place until the concrete has set. Back of the curb, six inches of concrete similar to that used in the foundation should be laid to a depth of ten inches.

After the curb stone has been set cement mortar or concrete should be poured into all open spaces either in the end joints or back of the curb. Portland cement grouting, consisting of one part of portland cement and one part of clean, sharp sand, should be poured over the concrete bed and backing until all interstices and open spaces at the end of the stones are completely filled.

Should this method of laying the curbing prove too expensive, sand and gravel or cinders may be substituted for the concrete. In this case, the cinder or sand and gravel foundation should be laid to a depth of six inches and thoroughly compacted by tamping. Back of the curbing, sand and gravel or cinders should be filled for a space of from six to ten inches. A single flat stone should be imbedded in the foundation underneath each joint to support the ends of the curb stones. The upper surface of these stones should be smooth and each stone should support an end of two adjacent lengths of curb.

Where the combined cement curb and gutter is used, the earth should be excavated to a depth of twelve inches below the under surface of the gutter. The sub-soil should be thoroughly compacted by wetting, rolling or ramming, and covered with a layer of clean cinders or gravel which will have, when consolidated, a thickness of seven inches. Upon this foundation should be

spread a layer of concrete made up of one part of portland cement, three parts of clean, coarse sand and five parts of clean, broken quartzite, granite or limestone composed of pieces from one to one inch and a half in diameter. The thickness of the gutter part should be four inches and that of the curb six inches. The curb should be sufficiently high to conform to the grade of the sidewalk.

Before the concrete beds have set, a layer of cement grouting composed of one part of portland cement and one and a half parts of fine, crushed granite or quartzite screenings should be spread over the surface. The surface layer should have a thickness of one inch and should be troweled to conform to the desired grade. The smoother the surface of the gutter the more efficient will it be in removing the surface water.

The combined cement curb and gutter should be made in blocks ranging from three to five feet in length as preferred by the engineer. (See Plate XXV.) The line of separation between the blocks should be perfect and distinct. The edge of the block should be made parallel to the length of the street, and the gutter should be made to conform to the crown of the pavement. In all cases the gutter at the line of junction with the pavement should be one half to one inch below the grade of the finished pavement.

The combined cement curb and gutter, constructed in this manner, is well suited to all streets except those having park areas between the curb and the sidewalk. Wherever a grass plot is left next to the curb, it is thought that this style of curb and gutter construction is both unnecessarily expensive and inaristic. I believe that a well constructed gutter having a depth of five or six inches and a breadth of thirty or thirty-five inches, meeting and conforming to the grade of the grass plot on one side and the crown of the pavement on the other, is far more desirable for parked streets. This method of constructing gutters is used almost exclusively on residential streets in some of the eastern cities but very seldom in Wisconsin. Under the description of the improved streets of Baraboo, there will be found illustrations of this gutter as constructed by W. G.

Constructing Combined Cement Curb and Gutter before Laying Macadam, East Mifflin Street, Madison, Wis.

Kirchoffer, city engineer. It has proved equally as serviceable as the combined curb and gutter, is less expensive and gives the street a better appearance. This style of gutter is especially recommended where asphalt, wooden block, macadam or bituminous macadam pavements are constructed on residence streets.

The width and depth of a gutter should depend upon the maximum volume of water which it is called upon to carry. If the pavement is constructed on a somewhat steep grade and the street has a considerable tributary area, the gutter should be made wider at the bottom of the grade than at the top. In case the roadway is winding and the grade steep, underground storm water sewers should be constructed in order to carry the water away without flooding the pavement. Wherever there is a turn in the roadway sufficient to divert the water from the gutter into the street, there should be an inlet to an underground sewer by which the water can be removed without flowing over the pavement. Engineers and street superintendents must remember that water flowing in a gutter or any other channel will not turn a sharp corner without overflowing. There is nothing to prevent the water from overflowing the gutter, and unless an underground inlet is provided the storm water will wash over the pavement, causing injury thereto. Macadam pavements probably suffer more than any other class from this cause.

One of the most conspicuous errors made by engineers in Wisconsin in the construction of gutters is the tendency to make them all of the same size without regard to the volume of water which they may be called upon to carry. A second mistake is in the construction of the combined curb and gutter in places where only the gutter is necessary. A third is the neglect to provide underground sewers to carry off the surplus water. In many cities a perfect system of surface drainage can only be established when there is combined with it an underground system of storm sewers.

The following specifications copied from those used in Waukesha and Madison give the usual details of construction:

WAUKESHA.

Combined Cement Curb and Gutter.—"The combined curb and gutter shall consist of a curb five inches wide at the top and having seven inch face above the gutter, and a gutter fourteen inches wide. The same shall be constructed in alternate sections or stones six feet in length. The face corner of the curb to be rounded to a radius of one and one-half inches, the gutter to be laid to a pitch to correspond with the crown of the street. The whole to be shaped as shown on plan.

"At the street corners the curb and gutter to be rounded to a true quarter circle of a radius of six feet and at the alley and private driveway corners to a true quarter circle radius of two feet.

"The space over which the curb and gutter is to be laid shall be excavated to a depth of nine inches below the finished surface of the gutter flag and filled in with cinders or gravel four inches thick, well rammed. On this foundation shall be constructed the concrete four inches thick. The whole will be so constructed as to make the curb and gutter monolithic. The concrete shall consist of three parts of No. 3 crushed limestone and three parts sharp bank sand or fine gravel and one part of American Portland cement which stands the highest test by cement tester at Milwaukee.

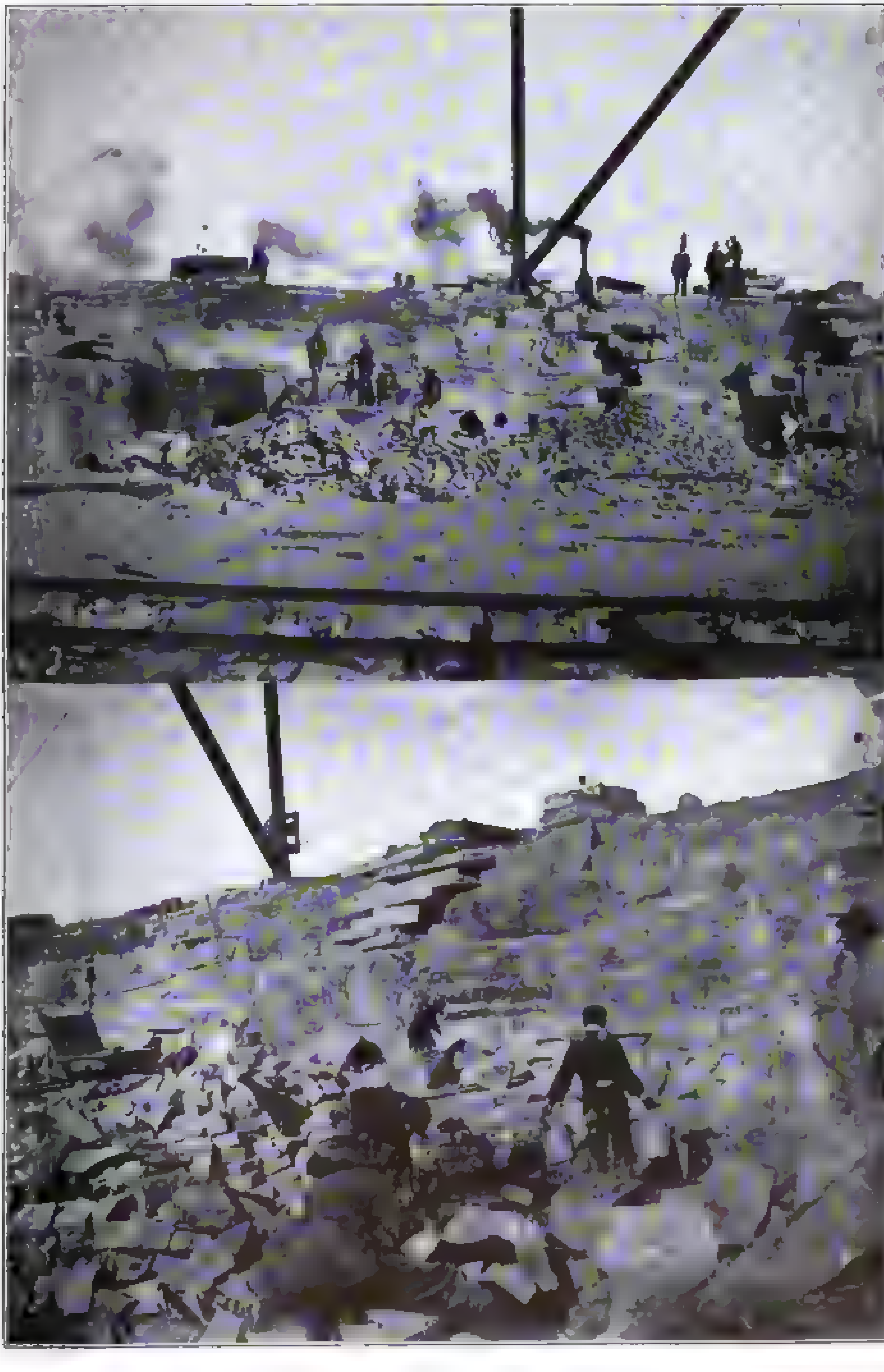
"The sand, stone and cement shall be mixed dry, then made into a mortar with a sufficient amount of water. When spread into the mould it should be rammed until clean water appears on the surface. The second or finishing layer shall consist of two parts Portland cement and three parts of screened bank sand, and No. 4 crushed granite mixed in proportion to give the best results and is to be put upon the concrete one inch thick before the concrete has become dry.

"The cement, sand and granite shall be mixed dry, after which sufficient water shall be added and the mortar mixed into a uniform paste which shall be laid upon the concrete and troweled or rubbed to a hard, smooth surface and finished with a broom.

"The curb and gutter must be protected from injury and kept moist and protected from the rays of the sun until perfectly set.

"The contractor will provide and use all necessary stakes, planking, clamps, etc., required to properly shape and guide the alignment and grade of the curbing and gutter.

"The contractor must construct the cement curb and gutter in such a manner that no settlements, cracks or any other defects due to bad materials or faulty workmanship shall appear therein for a period of two years after the completion of the work, and in the event of the failure of the curb and gutter to conform with this requirement during the period of two years the contractor must make prompt repairs at his own expense upon ten days' notice in writing by the City Engineer at Waukesha, Wisconsin."



Curbing Quarries. Menomonee Falls-Lannon Stone Company, Lannon, Wis.

MADISON.

"Combined Cement Curb and Gutter.—At such places and for such distances as shall be designated by the engineer the contractor shall construct a combined curb and gutter as follows: The space over which the combined curb and gutter is to be laid shall be excavated to a depth of 14 inches below the finished surface of the gutter flag. The bottom of the trench shall be thoroughly compacted by ramming, any depressions which may appear being filled with suitable material and properly consolidated. The trench will then be filled to a depth of eight inches when completed with old macadam stone from the adjoining street, blended with fire box cinders, and the whole thoroughly tamped to a uniform and unyielding surface. Upon this foundation after wetting, the combined curb and gutter, consisting of a curb six inches thick and varying from seven inches to eight inches in height above the gutter flag, shall be constructed in alternate sections of stones approximately six feet in length. The gutter flags shall be six inches in width from the face of the curb, and both curb and gutter shall conform in dimensions to the drawings thereof. The combined curb and gutter, excepting the outer or exposed face thereof for one inch in depth, shall be composed of portland cement concrete, as specified; thoroughly rammed into place, until all voids shall be filled with mortar and free mortar appears on the surface. The second or finishing layer, composed of granite mortar as specified, shall be put upon the core, one inch in thickness, before the core has become dry. The surfaces and edges of the curb and gutter must be left true and exact and free from tool marks. The curb and gutter must be protected from injury and kept moist and protected from the rays of the sun until perfectly set.

"The surface of the curb and gutter shall be thoroughly troweled and finished with a brush at right angles to the line of the curb and gutter. The contractor must construct the curb and gutter in such manner that no settlement, cracks, disallignment, or any other defects due to bad materials or faulty workmanship shall appear therein for a period of two years after the completion of the work—only such cement shall be used in this work as complies with the foregoing specifications and has been proven to be suitable for such work by extended use. The contractor shall build, without extra charge, all 'inlets' necessary to properly connect the curb and gutter with the culverts, and such retaining curbs at crossings as the engineer may direct. The corners at streets and driveways shall be turned to such radius as the engineer shall specify. In case the present curb or curb and gutter or parts of them are to remain, the manner of connecting the new work with the old shall be specified by the engineer and the

expense thereof be determined by the contractor and engineer before the work shall be done, upon the basis of the prices bid for similar work."

GRADIENT AND CROWN.

Perhaps no two factors in the construction of streets have called forth as general a discussion as the "grade" and "crown" of the pavement. I have expressed myself in the first part of this report on the subject of grades. I believe that they should be reduced as far as possible in the business parts of a city, but in the resident districts it is believed that the grades should conform as nearly as possible to the natural contour of the country. There are many reasons why grades should be reduced as much as possible. Some of these are expressed in the following quotations. Sir John McNeil, a European authority on road construction, asserts that "If a road has no greater inclination than one in 40, there is 20 per cent less cost for maintenance than where the inclination of the road is one in 20. This," he says, "is due both to the action of horses' hoofs and to sledging and breaking of the wheels in descent. The traction force required on a macadam street with an angle of repose of 50 is twice that required on a level."*

James D. Reid in this same report asserts that, "Easy gradients are preferable to dead levels, securing drier and more compact roads." In this same report the chief engineering inspector of the local government board of highways in England and Wales says, "If a ruling gradient of about one in 30 could be generally adopted throughout the country except for very short distances and in cases where the cost would be out of all proportion to the advantages gained, an immense benefit would be derived by the public.†

Gillispie in his report on road construction informs us that "It is profitable to the traveler to go 2,000 or 3,000 feet around to avoid ascending a hill 100 feet high." From these observa-

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*Special Consular Reports on Streets and Highways, Government printing office, 1891. Vol. 3, page 411.

†Ibid., page 595.

Cement Gutter without Curb, Ash Street, Baraboo, Wis.

tions one is led to conclude that a gradient of one in thirty or one in forty increases very materially the cost of traction. However, we are constantly expending money to gratify our desire for the beautiful and artistic. The beauty of many a city lies in her hills and our better sense rebels against cutting them down in order to make level roads.

The crown of the pavement should depend upon the gradient and width of the street. If a pavement is extremely convex, the people will travel in the middle of it; if it is flat, they will travel on all parts alike. In the case of the first pavement, there is a tendency to make ruts, while in the latter this is avoided. In one of Telford's specifications he gives the following rule with regard to the crown of the pavement: "In giving a convexity of six inches to a road of 30 feet in breadth, the convexity at four feet should be only one-half inch, at nine feet two inches and at fifteen feet six inches. This will give the form of a flat ellipse." Giving the surface of a road an elliptical shape is thought by some to be an advantage over the usual crown which makes the slope uniform from the center to the sides of the pavement.

The aim in crowning a pavement is to give it such a slope that the water falling on the surface will be removed by the shortest possible course and with least injury to the pavement. A high crown where the gradient is steep will deflect the water into the gutters much more rapidly than one which is flat. The water flowing off from the surface of a street is an active agent of erosion, and if permitted to flow lengthwise of the pavement it will constantly increase both in volume and velocity. Any increase in the volume or velocity of a stream increases greatly its erosive power. For this reason the surface water should be conducted by as short a route as possible into the gutter.

WIDTH OF PAVEMENT.

The width of a pavement should depend primarily upon the width of the highway. In the business sections of a city, all of that portion of the highway which is not occupied by the sidewalk should be devoted to the curb, gutter and pavement. The

fact that many of the cities have been laid out upon a narrow plan often accounts for the business streets being scarcely wide enough to accommodate the traffic. Owing to the frequently congested condition of these thoroughfares, new streets that are laid out are often broad avenues that are wider than is necessary to accommodate the traffic. It frequently happens that these broad avenues are paved from curb to curb, involving an expense for construction and maintenance that is altogether unnecessary.

All residence streets should consist of a central pavement for carriages and horses, gutters to carry off the water, park areas for grass and shade trees and sidewalks for pedestrians. The pavement should be sufficiently broad to accommodate the traffic but any greater width is unnecessary and expensive. Next to the property line on both sides of a street there should be laid off an adequate width of the highway for sidewalk purposes and the remaining space between the sidewalk and the pavement should be set aside for park purposes. This plot of ground should be sodded and planted with one or two rows of shade trees, depending upon its width. The planting and care of the shade trees, as well as the sodding of the park, should be under the immediate supervision of the street superintendent. The planting of the trees and the sodding of the ground should be in accordance with some general scheme adopted by the board of public works. The maintenance of this, as well as all other parts of the highway, should be under the supervision of the street superintendent and should be paid for by the abutting property owners (two-thirds), and from the general fund (one-third).

Accompanying the discussion of the Madison pavements will be found several plates illustrating the methods of parking the streets in that city.

SIDEWALKS.

In all parts of Wisconsin, up to within a few years ago, it has been customary to construct most of the sidewalks out of wood. In some places one-inch pine boards have been used and in other places two-inch oak planks. In some cities the side-

Cement Combined Curb and Cutter in Process of Construction, Michigan Avenue, Sheboygan, Wis.

walks have consisted mainly of two planks twelve inches wide, laid side by side, making a walk two feet wide. In other places, walks have been constructed six or eight feet wide. The width of the sidewalk usually varies with the traffic on the street and the distance from the business center. If one should start from the business section of any of the smaller cities in Wisconsin and follow a main thoroughfare out into the country, he would pass over sidewalks which constantly decrease in width until he stepped from a single board into a narrow, beaten foot path. Also, as a rule, the materials change from stone, cement or brick to wood as the outskirts are approached. In nearly every city there are examples of sidewalks which have been constructed without any regard for the amount or character of the traffic which necessitates their construction.

In many cities wooden sidewalks have undoubtedly been the most expensive item in the cost of maintaining the public thoroughfares. This has not been due to the excessive cost of lumber or labor but has resulted mainly from the cost of personal injury cases brought against the cities on account of defective walks. Wooden sidewalks in themselves are not everywhere costly to construct but unless they are kept in perfect repair they are very unsatisfactory to the pedestrian.

At the present time the wooden sidewalk is being rapidly replaced by flag stone, cement concrete, bituminous concrete and brick. In some Wisconsin cities the building of wooden sidewalks within certain districts is prohibited.

The usual sidewalk on a business street has a width of from twelve to twenty feet. Along residence streets, a width of four feet is usually adequate to accommodate the traffic. All sidewalks within the corporate limits of the city should be under the direct supervision of the street superintendent.

In the construction of portland cement concrete (granolithic) walks the same cautions should be observed as in the laying of concrete foundations for brick or other pavements. The strip upon which the sidewalk is to be constructed should be excavated to a depth of eight to ten inches below the finished grade of the walk and parallel to it. Soft or mucky material should

be removed and replaced with clean sand, cinders or gravel, all of which should be firmly compacted by ramming or rolling. After the subgrade has been made to conform to the finished grade of the sidewalk, it should be covered to a depth of four inches with clean cinders or cubical broken stone. This layer of cinders or broken stone may be omitted where the subsoil is sand or gravel. After this layer has been thoroughly wetted and compacted by ramming or rolling, a layer of concrete, three and a half inches in thickness when compressed, should be spread evenly over the surface. Where driveways cross the sidewalk, the thickness of this layer of concrete should be increased to seven and a half inches.

After the concrete has been spread, it should be rammed until free mortar appears at the surface. Before the concrete is dry the finishing layer should be added. This layer should have a thickness of one inch and should be composed of one part of portland cement and one part of crushed granite or quartzite, the particles of which should not be larger than one-fourth of an inch nor less than one-eighth of an inch in their greatest diameter. In preparing this finishing mixture, the cement and crushed granite should be mixed dry, after which sufficient water should be added to make a uniform paste. The surface layer should be troweled to a hard, smooth surface after which it should be corrugated by brooming.

The sidewalk should be laid in alternate sections not more than four feet long. At crossings, alleys or entrances to private driveways, the cement concrete should be connected with the gutter and laid in longitudinal strips not over four inches in width, lengthwise of the sidewalk.

At street intersections it has not been thought advisable to construct the cross walks of cement concrete, although the approaches to the sidewalk, extending out as far as the gutter, are, as a rule, built out of cement concrete.

The gutters are usually spanned with iron aprons which connect the cement approaches with the crosswalk.

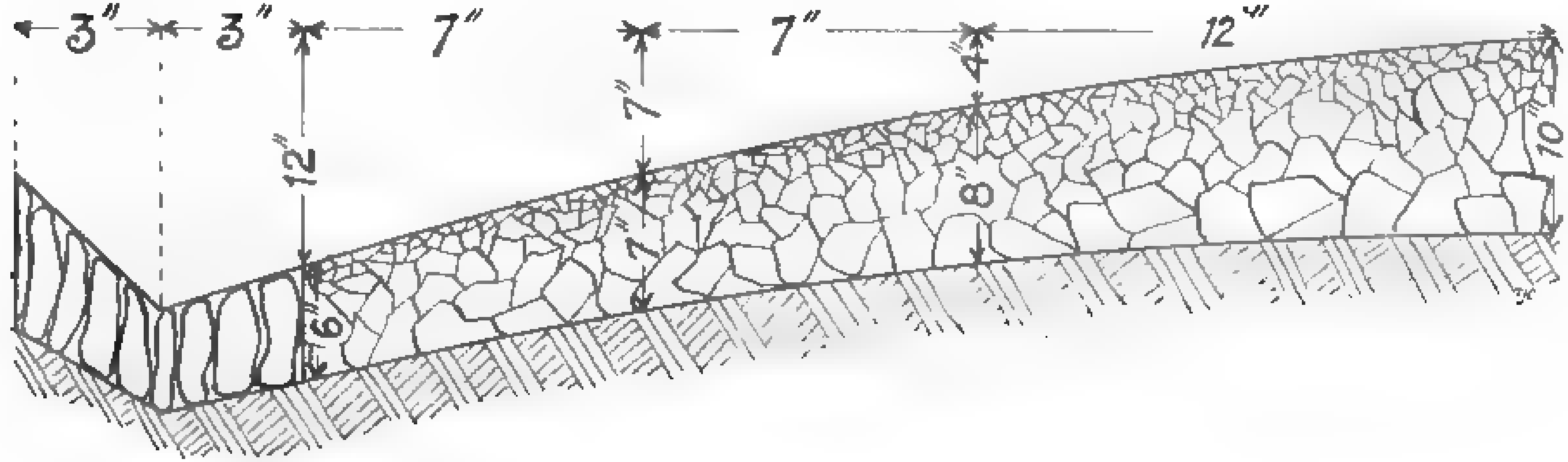
One of the chief objections to the granolithic sidewalk is its extremely slippery surface. The slipperiness, however, can be

CROSS SECTION OF MACADAM PAVEMENT

ANTIGO WIS.

HORIZONTAL SCALE ¼" = 1'

VERTICAL " 1/10" = 1"



lessened in several ways. The surface can be grooved or corrugated; the walk can be laid in smaller sections; or coarser material can be used for the surface layer. The practice of troweling the surface, which has been so common, should be stopped. The surface of the granolithic walk should be broomed and not troweled. Brooming the surface of the walk gives it a roughness which is very desirable. Further than this, it has been the practice to cover all the coarser particles of the surface layer with cement grouting, leaving it very smooth. This is very desirable in the case of cement gutters where a smooth surface is required, but is not satisfactory for sidewalks. Instead of surfacing the walk with grouting, free from coarse particles of stone, the grouting should contain an abundance of crushed granite or quartzite fragments from one-eighth to three-eighths of an inch in their greatest diameter. The public may object to this method of construction on the ground that the roughness of the surface has a tendency to wear out shoes. However, the municipal authorities must expect that the public will complain either that the pavement is too slippery or too rough. If we are to choose between a rough and a smooth pavement, it will be safer to select the former.

Flag stone or brick sidewalks should be laid on a concrete foundation similar to that suggested for the cement concrete sidewalk above described. A concrete foundation, four inches in thickness, consisting of portland cement and clean broken stone, should always be constructed. Upon this foundation there should be spread a cushion of sand an inch or an inch and a half in thickness, upon which the brick should be laid on the flat side, crosswise of the pavement. Brick of special shapes are now manufactured for sidewalk purposes. Sidewalk brick should have corrugated surfaces and should be larger than the ordinary paving brick. The block size of the paving brick is preferrable to the building size for sidewalk construction.

Whatever kind of brick are used, it is important that they should be laid on a well constructed foundation and that the surface be made impervious by filling the joints with portland cement grouting, as in the case of brick pavements.

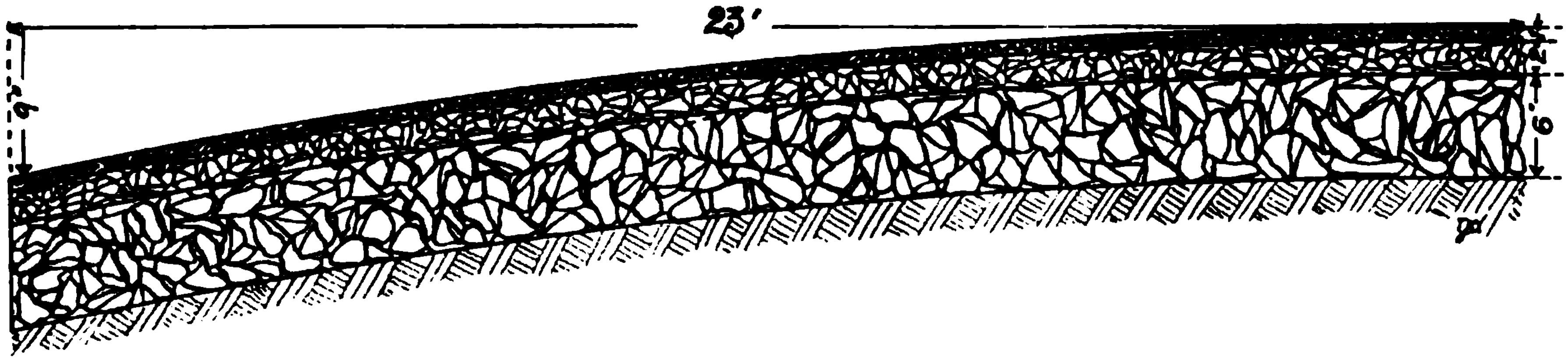
Brick which are used for sidewalk purposes should be thoroughly vitrified. Common building brick, such as have been used in some Wisconsin cities for sidewalk purposes, are altogether unsuitable to withstand the friction to which they are subjected. Some of the brick factories in Wisconsin are manufacturing what is known as a sewer brick, a hard burned common brick, which if carefully selected can be used for sidewalk construction. The use of soft building brick for sidewalks in some of the cities has unfortunately prejudiced the public against the use of brick of any kind. This prejudice which works against the use of vitrified as well as building brick is entirely unwarranted. Building brick are seldom suitable for sidewalks, but vitrified brick are very satisfactory when properly laid.

A brick pavement constructed out of semi-vitrified brick is less slippery than one constructed out of brick which have been thoroughly vitrified. For this reason I am inclined to believe that semi-vitrified brick should be used in preference to the very hard brick which are specified for street pavements. The corrugated brick which are being manufactured at the present time are much less slippery than the ordinary paving brick and should always be given the preference.

Flagstones have been used very generally for sidewalk purposes throughout Wisconsin. Various kinds of stone are used for this purpose, the most important being granite, limestone, sandstone and rhyolite. With the exception of the sandstone, most of these become slippery with wear. It is often necessary to re-dress the limestone and granite flagstones when they become so slippery as to be unsafe. Although sandstone, as a rule, is the surest and safest sidewalk stone, it usually wears away more rapidly than either of the other kinds. If a sandstone chances to be a little soft, it will wear so rapidly as to require replacement in a few years. If the sandstone is hard, approaching the nature of a quartzite, it takes on the same characteristics as the granite, and will become slippery with age. A semi-indurated sandstone is considered the best all around stone for sidewalks for any but the business streets. A coarse grained granite is equally as desirable but is usually much more ex-

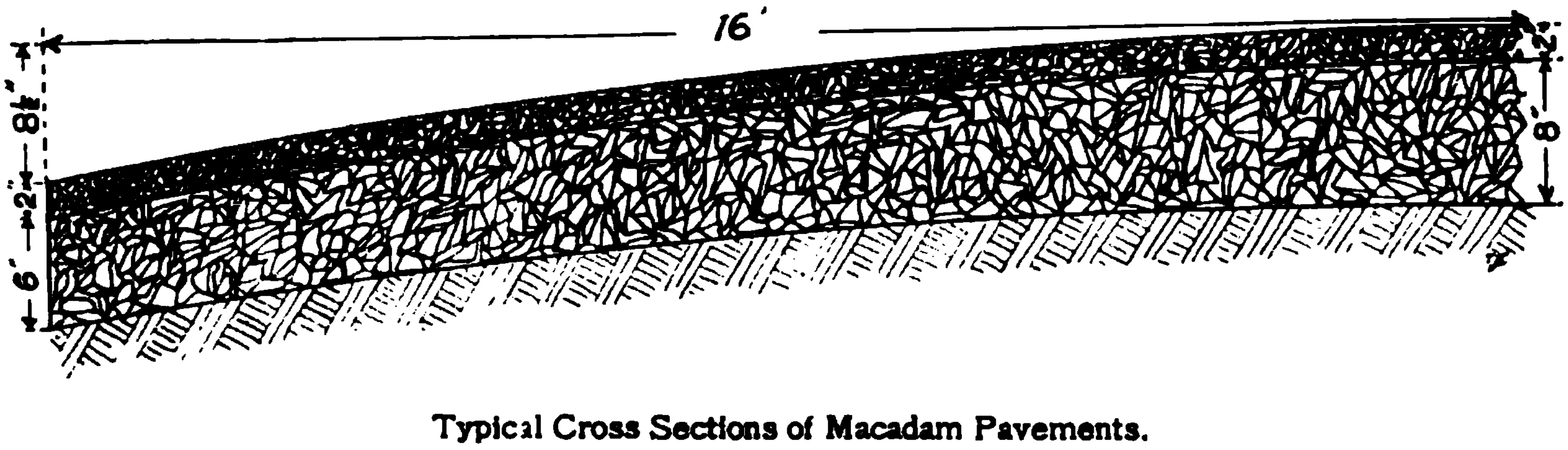
CROSS SECTION
MACADAM PAVEMENT.
MERRILL WIS.

HORIZONTAL SCALE 3/16"=1'
VERTICAL " 1/10"=1'



CROSS SECTION
MACADAM PAVEMENT
STEVENS POINT WIS.

HORIZONTAL SCALE ½"=1'
VERTICAL " 1/10"=1"



Typical Cross Sections of Macadam Pavements.

pensive. Limestone flagging is the least expensive of all, and on account of its greater strength has been used in preference to sandstone. Along business streets in large cities, limestone, granite and rhyolite are the only stones in Wisconsin which can be used with safety. Except for the business streets of the large cities and to supply the needs of the rural districts, there will be very little future demand for flagging stones for sidewalk purposes. Portland cement concrete (granolithic) walks are so much cheaper and the materials so much more accessible that they are everywhere rapidly replacing the flag stones.

There is no sidewalk, cement concrete, brick or flag stone, which will not be slippery if covered with ice. Every kind of sidewalk will sooner or later have depressions on its surface in which water will accumulate and freeze during cold weather.

In order that the water which falls on the sidewalk may be quickly removed, it should slope toward the street at the rate of about one inch in ten feet.

The sidewalk or street pavement may have a color which is dazzling and consequently annoying to the eyes. A white marble building is beautiful when viewed in the soft rays of a full moon, but the dazzling reflection of a noonday summer's sun is almost unbearable. A black pavement is sombre and unattractive and absorbes the heat from the sun, making the surface often unbearably hot. The red or brown colored pavement or sidewalk is more pleasing than the black but this still has a capacity to absorb and retain the heat, making the pavement frequently a source of annoyance during the hot summer days. The reddish brown paving brick which are used so extensively on the streets of some of our cities increase very materially the temperature of the atmosphere in their immediate vicinity. During the middle of the day the brick absorb the heat giving it off again as the surrounding atmosphere cools off in the evening.

Every one has had more or less experience using a soapstone or brick to keep the feet and hands warm during winter journeys. The brick pavement, the same as the soapstone, acts as a storage rerservoir for the heat of the noonday summer's sun. When evening approaches the heat is given out again to the at-

mosphere of the narrow street. This same absorption and radiation of heat takes place in the case of asphalt and stone block pavements as well as brick.

I have always thought that the most pleasing color for a sidewalk or pavement, and the one which would be the least injurious to the eyes, would be a dark green. The trap rock macadam pavement comes nearest to a green color of any which is now being built. However, the color of this pavement is not exactly green, being more on a grayish order. The glass blocks which are being manufactured in France, and which may be used for either street pavements or sidewalks, may come more nearly to supplying the desired color than any material now on the market.

CROSS WALKS.

Cross walks may be constructed out of stone, brick, asphalt or wooden block. The material used usually depends upon the character of the pavement. In the case of a granite block pavement, the crossings are usually constructed out of three rows of crossing stones laid one-half inch above the adjoining pavement and resting upon a sand cushion in the same manner as the paving blocks. The best crossing stones are granite or rhyolite, having a foundation width of sixteen inches, a depth of from six to seven inches and a length of from three to five feet. The top surface should be smooth and the ends squared and hammer dressed so as to form close joints to their full depths. The crossing stones should be laid one foot apart and to grade as specified by the engineer.

A raised stone protection curb four inches in thickness and eight feet long should be set so as to leave a gutter eight inches in width next to the street curb. The top of the protection curb should be two inches below the crossing pavement.

In the case of a brick pavement each street and alley cross walk should be elevated for a width of at least eight feet, with a gutter of eight inches clear width next to the curb. A raised stone protection curb four inches in thickness and ten feet in length, should be set in concrete, so as to leave a gutter eight

Typical Flagstone and Stone Block Crosswalk, Milwaukee, Wis.

inches wide next to the street curb. The top of such protection curb should be two inches below the crossing pavement.

Where the pavements are of broken stone and the cross walks are of brick, the latter should be at least eight feet wide; should be laid on a concrete foundation at least four inches thick; and should have a crown of three or four inches. The concrete foundation should be constructed as in the case of a brick pavement and the brick should be laid on edge and grouted in a similar manner.

Where flag stone or asphalt cross walks are used, they should be constructed in the same manner as flag stone sidewalks and asphalt pavements.

One of the chief criticisms which one can make on the cross walks in most Wisconsin cities is that they are too narrow. The cross walks are not broad enough either to accommodate the public, or to keep the wheels from covering them with mud and refuse. The tendency has been to construct narrow cross walks with flat crowns. An attempt has been made in this way to minimize the cost and at the same time cater to the driving public by maintaining a smooth pavement. The public, as a whole, is best accommodated by a wide crossing with a gentle gradient. If the cross walk is wide the crown may be higher than in the ordinary narrow cross walk and yet be less disagreeable to passing vehicles.

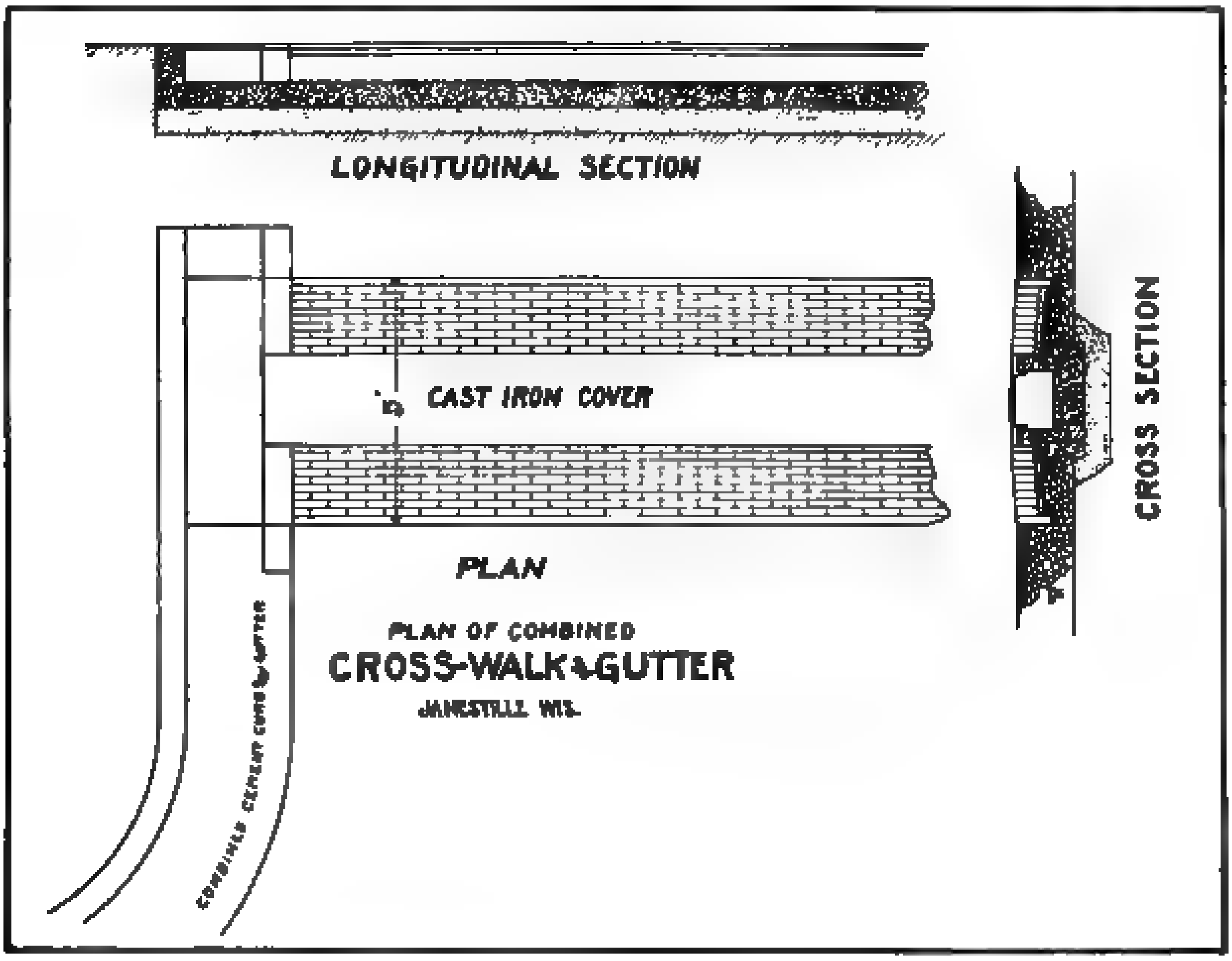
CHAPTER IV.

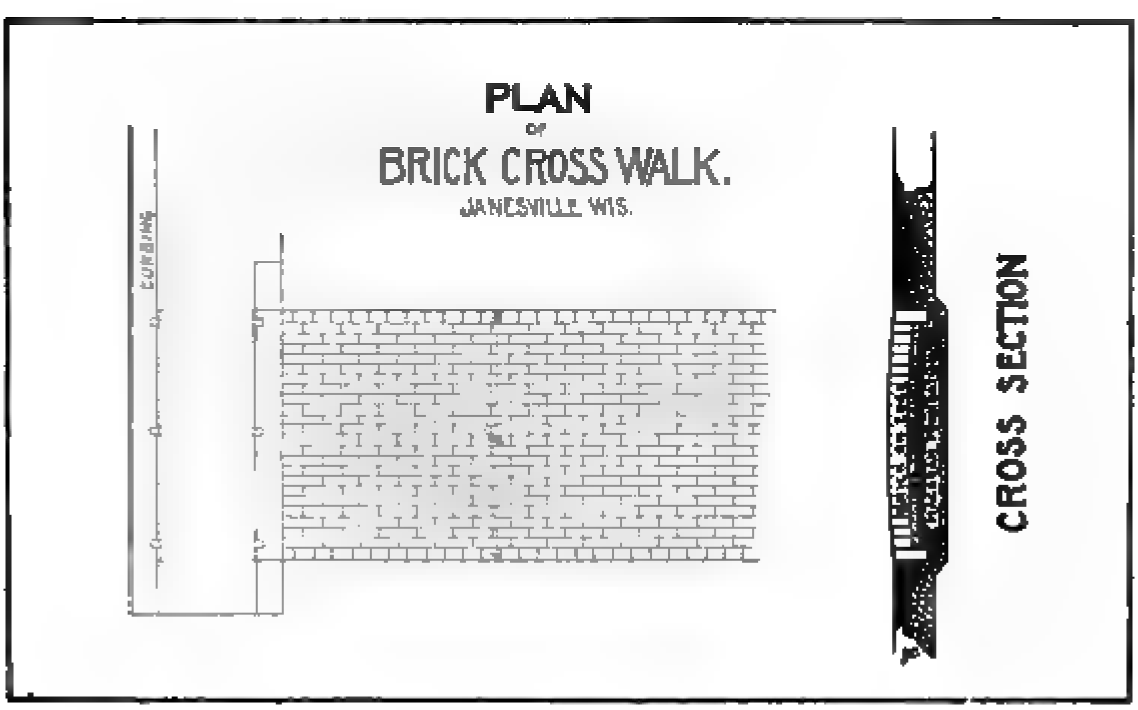
DRAINAGE.

The establishment of conditions whereby a road bed will be comparatively dry at all seasons of the year deserves the most careful consideration in the construction of any pavement. MacAdam has truthfully said "That while a road is preserved in a dry state, it will carry any weight without sinking and that it does in fact carry the road and the carriage also." A poorly drained road, besides increasing the power for traction of loaded vehicles, involves an extravagant expenditure of money for maintenance during wet weather. In the construction of any pavement provision should be made for the removal of water which may seep into the sub-grade, as well as for the removal of that which remains upon the surface. In case the sub-soil is poorly drained, and especially if it is of a finely porous nature, the pavement will be injured through the absorption of water.

A pavement should be so constructed that the water which falls upon the surface will be carried off unobstructed to the drainage channels on either side. If this is done a somewhat porous pavement may be rendered practically impervious. A pavement with an uneven surface will gather the rain water into puddles, which will in time saturate almost any of the common pavements.

Two classes of drainage, surface and underground, are ordinarily distinguished in a discussion of street constructions. Underground drainage, as the term implies, is the removal, by means of underground drains, of water which finds its way into the





Plan of Cross Walks and Gutters, Janesville, Wis.

pavement or the underlying sub-soil. Surface drainage, on the other hand, is the removal of the surface water by means of open gutters and underground sewers.

The removal of the underground water is accomplished by means of underground drains. The removal of the surface water is accomplished either by gutters alone or by gutters in conjunction with underground sewers. Whether underground or surface drainage or both are established depends altogether upon local conditions. The size and depth at which the drains are laid also depend upon the location of the pavement.

UNDERGROUND DRAINS.

Underground drains may be constructed crosswise or lengthwise of the road. Occasionally a combination system of longitudinal and cross drains is used, but more frequently the drains are laid in a single direction. Longitudinal drains may be constructed either in the middle of the road or on one or both sides. These drains may be built out of broken stone, poles and brush, flag-stone or drain tile, as illustrated by the accompanying drawings. See Pl. XXXIII. The drains should be constructed sufficiently deep to be out of danger of frost under normal atmospheric conditions and should be large enough to accommodate the maximum flow of water at any season of the year. Further, they should be of such shape and so laid that the water passing through them will remove all earth which may chance to seep in through the joints.

SURFACE DRAINS.

Storm Water Sewers and Gutters.—The surface drains or gutters at the roadside should be made large enough so that they will not overflow during heavy storms.

In a perfect system of storm water drainage it is usually necessary to combine underground storm water sewers with surface gutters. Wherever the accumulation of water in the surface gutters becomes so great as to require the construction of

gutters out of proportion to the width of the street, they should be connected with underground sewers through which the water may be carried outside of the city. Underground storm water sewers are very necessary where the grades are steep. Steep grades increase the velocity of the water, multiplying the erosive power of the running water. This accounts very largely for the occurrence of deep gulleys near the bottom of many of the country roads.

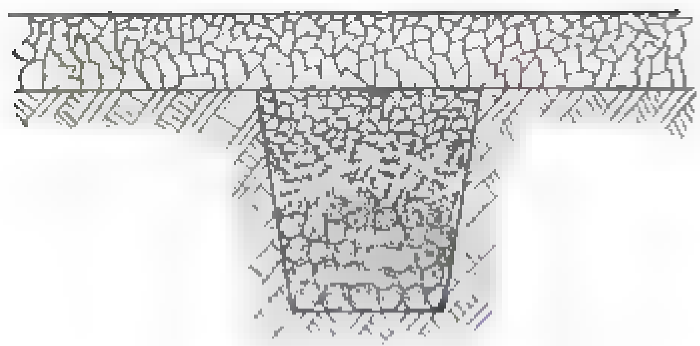
In cities where the domestic sewerage system empties by gravity into a lake or stream, the storm water may be carried into catch basins and from thence into these sewers. In fact the storm water flowing through these sewers, at intervals, cleanses and purifies them to such an extent as to be very beneficial. In case a city is so situated as to make it necessary to pump the sewerage, the storm water should be carried off by a separate system of sewers.

Storm water sewers may be constructed out of cement, vitrified pipe, brick or iron pipe. They are not intended to drain the pavement or sub-soil, but are constructed solely to remove the water which flows in the gutters. For this reason they should be made water tight. They should be of large size and in order to insure a strong scouring action, a narrow base and a broad top are desirable.

The kind and size of sewers to construct, and the depth at which they should be laid, are questions which must be answered separately for each locality.

The question of gutter construction is more closely connected with street paving than that of sewers. The gutter is, in reality, a part of the pavement and must be considered with it in any plan of street improvement. Situated as it is, next to the curb, the gutter is seldom driven over and cannot be objected to if it is both noisy and slippery. However, it must be durable and of such size and shape that it will quickly and effectually remove the surface water. It is important also in resident districts, that the curb shall be neat and artistic, as well as serviceable.

In the business section little or no attention is given to the



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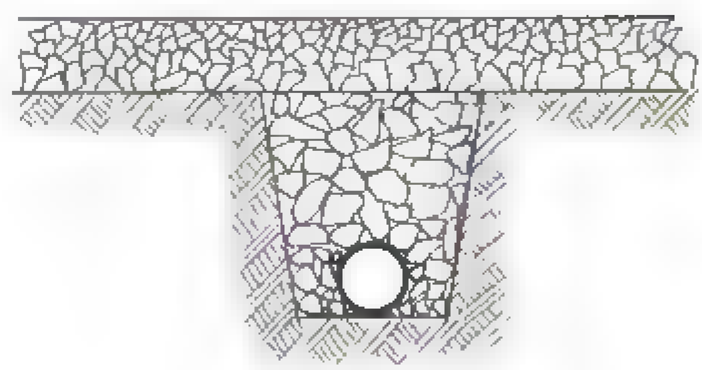

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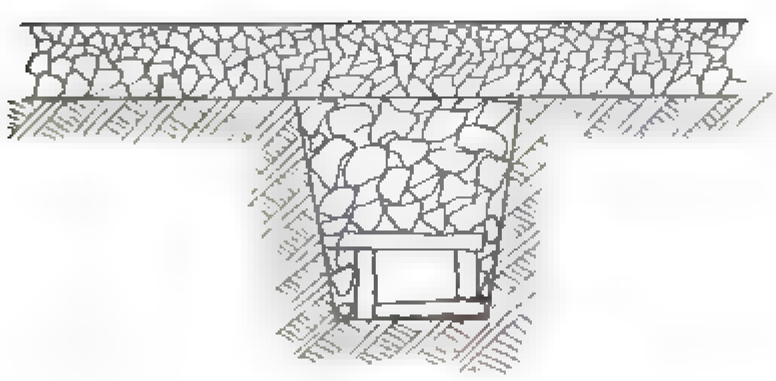

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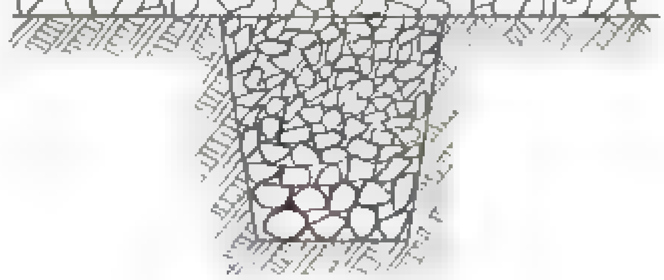

4.

Drains.

1.—Pole drain. 2.—Tile drain. 3.—Flagstone drain. 4.—Broken stone drain.

artistic features of the curbing, emphasis naturally being placed upon the question of serviceability. Along business streets provision must be made for the jolting of heavy teams and the pounding of draft horses as they wheel up alongside the curb.

Experience has shown that the curb and gutter should be laid on a strong substantial foundation. Stone, cement, brick, asphalt and coal tar compositions are all in common use for curb and gutter constructions. One of the commonest and most durable of these is the portland cement combined curb and gutter, illustrated in the plates accompanying this and the preceding chapter. The curb and gutter, as previously noted, can both be made of any thickness required to withstand the traffic. The form and size of the gutter and curb vary in different places.

Before pavements are constructed or sewers laid in villages, town or cities contemplating these improvements, sewer districts should be established. Definite plans should be made for the removal and disposition of both the sewage and storm water. A comprehensive plan should be made in which the city should be divided up into districts.

Along with the permanent improvement of the highways should come the laying of conduits for telephone and telegraph wires, gas pipes and such other underground constructions as may be necessary for the improvement of the municipal service. Every underground construction which will be needed during the life of the pavement should be in place before work is commenced on the pavement. One of the reasons for the early decay of city pavements is the laying of water pipes, gas pipes and sewer mains, on account of which the pavement must be repeatedly torn up and relaid.

The construction of asphalt pavements carries with it the desirability of using a combination of brick and stone for curb and gutter. In many instances no special gutter is constructed. However, on streets where the traffic is heavy, three or four rows of paving blocks may be advantageously laid next to the curb as illustrated in Plate XXXV. Stone, cement or vitrified clay curbing may be used with the brick gutter. It is custom-

ary, however, to use a good quality of stone, either granite or limestone, for this purpose.

In the construction of brick pavements, the brick are usually laid up to the curb, in which case the pavement itself serves as a gutter to carry away the water. It has been found advantageous to lay ten or fifteen rows of brick lengthwise of the street, raising several rows next to the curb, thereby forming a gutter which will keep the water away from the curb. The curb in this case may be either stone, cement or vitrified clay.

In the case of stone block pavements, it is usually unnecessary to provide a special gutter. The curbing, as in the case of brick pavements, may be stone, cement or vitrified clay. The use of stone block as a paving material is in itself evidence that the street is subject to very heavy traffic, and consequently it is important that the curbing should be of the strongest and most durable character. Heavy granite or concrete will prove the most serviceable.

In the case of a macadam or telford pavement one may choose between a cement combined curb and gutter; an asphalt or coal tar concrete curb and gutter; a flagstone gutter and stone curb; or a brick gutter with stone curb. Each of these constructions has its special advantage, depending upon the conditions under which it is used. The flagstone gutter is, as a rule, the cheapest to build, and if well constructed, it will prove serviceable for a great many years. For a residence street, however, it is somewhat untidy and has the disadvantage of collecting refuse from the water which flows off from the surface of the street. The brick gutter is also subject to the same criticism, but to a less extent. Both of these gutters are more durable than the broken stone pavement and should be used where other gutters are not available. For a broken stone road, cement concrete and asphalt concrete have proven most desirable. In business sections of the city the asphalt concrete is little used on account of its somewhat less durability, but in the resident sections and park areas the artistic feature of the gutter is important and it becomes a matter of taste whether cement or asphalt concrete is used for this purpose.

Combined Cement Curb and Gutter. Finished. Corner of West Washington Avenue and Broom Streets, Madison, Wis.

In business sections it is necessary to construct a curb which will protect the sidewalk, and consequently pedestrians, from heavy moving vehicles. In residence portions of the city, curbing is in many instances entirely unnecessary and can be omitted from the construction with perfect safety.

The omission of the curb from the street construction necessitates a modification of the usual gutter. The shape which should be used differs somewhat from the combined curb and gutter, as shown in Plate XXVII.

In some of the larger cities the alleys are paved with cobble stones and being somewhat narrow, the pavement is built concave at the center. This manner of construction necessitates a single gutter in the middle of the roadway. It has been suggested by some engineers that it would not only be less expensive but also more desirable to have a single gutter in the middle of the pavement rather than a pair of gutters, one on each side. The initial cost of construction would certainly be less and one has every reason to suppose that the cost of maintenance would also be proportionately less. There are, however, serious objections to this form of street construction. A gutter in the middle of the street would interfere with the construction of street railway tracks, to such an extent as to make even a consideration of this plan unwarranted. Loaded wagons could be backed up to the curb only with difficulty. The pavement would also receive the refuse washed from the sidewalk and adjacent land.

Culverts.—The culvert is that part of the surface gutter which is carried under the pavement at the street intersections. Where pavements are laid correctly the water carried by the gutters will pass under the pavement next to the cross walk or under the cross-walk itself. In many instances, however, culverts are not built and the gutter continues open. Culverts may be constructed out of wood, stone, brick, cement or sewer pipe. Sewer pipe, cement and brick are at the present time used most generally. A wooden culvert is at the most only a temporary expedient and should never be constructed except in a case of emergency.

Miscellaneous.—Among the miscellaneous constructions to be considered are man-holes, catch basins, flush tanks, lamp holes and valve-boxes. The manner in which these should be built and their relation to the pavement are discussed in all standard text-books on street paving. Care should be taken to see that the pavement surrounding these openings is well protected.

Brick Gutter, Cement Curb and Granolithic Sidewalk. Second Street, Milwaukee, Wis.
Corner of curb protected with steel plates.

CHAPTER V.

PAVEMENTS CONSTRUCTED IN THE LARGER CITIES OF WISCONSIN.

INTRODUCTION.

The purpose of this chapter is primarily to consider the different pavements constructed in the larger cities of Wisconsin and to point out some of the changes in methods of construction and materials used, which have resulted from these experiences. Accompanying the text are sketch maps of the cities showing the streets improved and the kinds of pavements in the various cities. In the text the cost of construction, the condition of the traffic, and the present condition of the streets are all reviewed as far as possible.

Unfortunately it has been impossible to obtain accurate or even approximate information concerning the pavements in some of the cities. The pavements in most of these cities, however, have been examined and an attempt will be made to discuss as impartially as possible the nature of the improvements which have been made.

In every county and in every locality in the county there is usually a choice between two or more rocks which can be used for the construction of broken stone pavements. If one knows the wearing and bonding qualities of the stones available, he can pass an intelligent judgment on which one should be used. It sometimes happens that a combination of two or more of the available stones will make a more durable pavement than either one used alone. For this reason it is important that there

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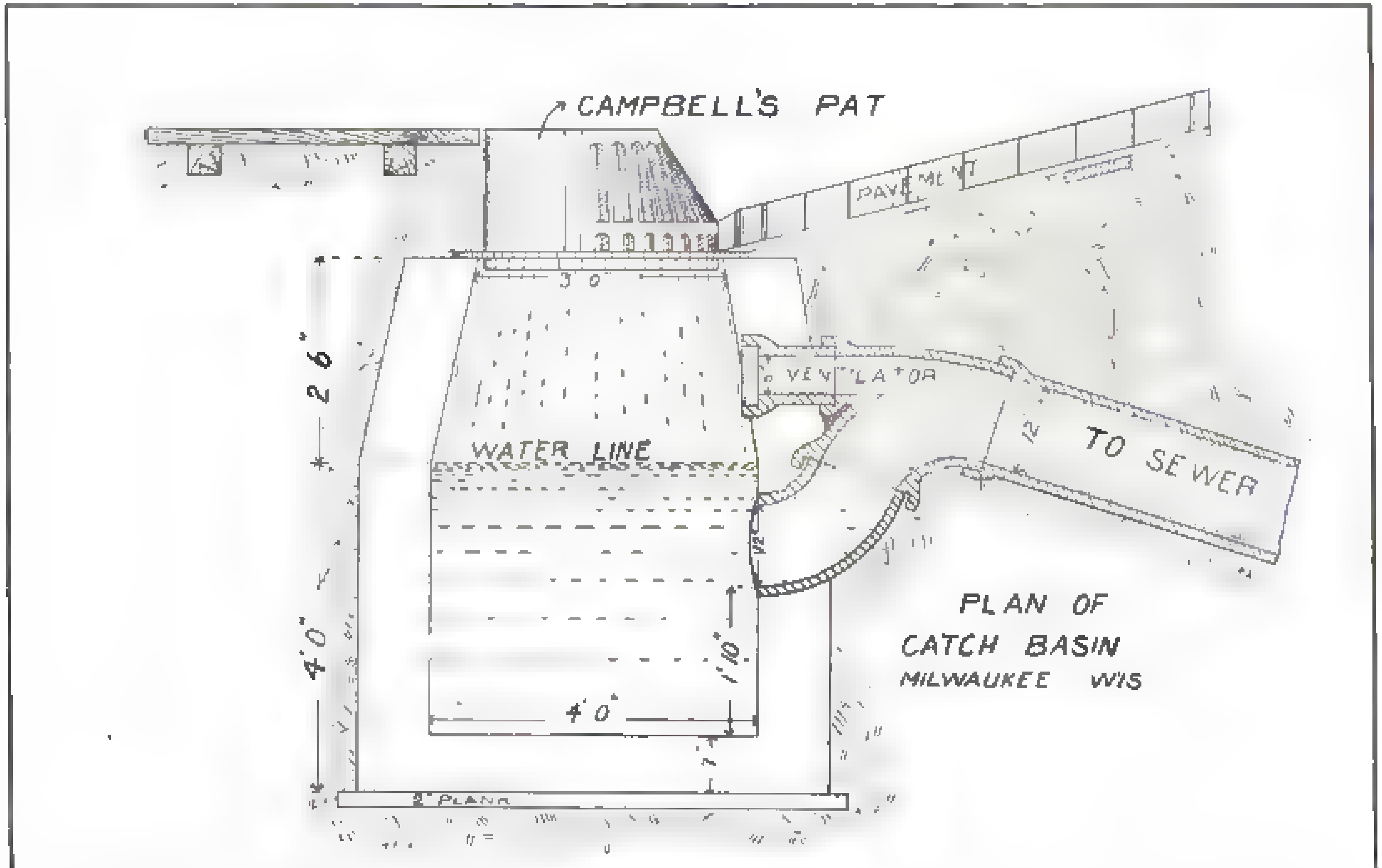
The too prevalent tendency to use the refuse from a quarry for street paving should be discouraged. The harder and most durable stone should be selected for this purpose whether it chances to be the best dimension stone or not. This applies especially in the case of limestones where a quarryman is willing



Plan of Catch Basin, Milwaukee, Wis.

should be some state department to which samples of road metal may be sent and from which advice can be obtained as to which of the different rocks is most suitable for the pavement to be constructed.

The durability of the broken stone pavement which it is intended to build, will depend upon the amount of traffic to which the road will be subject; the character of the subsoil; and the nature of the grades. It will be observed in reading over the brief account of the surface features of the counties, as published in this chapter, that in any single county a person will meet with almost every kind of soil and grades of almost every degree of steepness. Some portion of almost every county in the state is hilly; there is scarcely a county which does not possess low, swampy areas of land over which roads must be constructed; clay which is soft during the spring and fall, and sand which is dry and dusty during the summer, are met with more or less in most of the counties of the state.

A study of drainage, of the nature of the subsoils and of the durability of the available road metal, for each county in the state, would assist very greatly in the permanent improvement of the highways wherever such work was performed.

The data with reference to the topography of the different counties, the soils, the glacial deposits and the underlying formations which follows in the discussion of the counties, have been taken very largely from the maps published by the Wisconsin Geological Survey in 1871-73. To the data at hand in these maps, I have added such information and knowledge as has been obtained through field work in the state during the last five years. There is nothing specific in the statements made concerning the counties but it is hoped that the suggestions made therein will lead to a more careful and detailed investigation at a later time.

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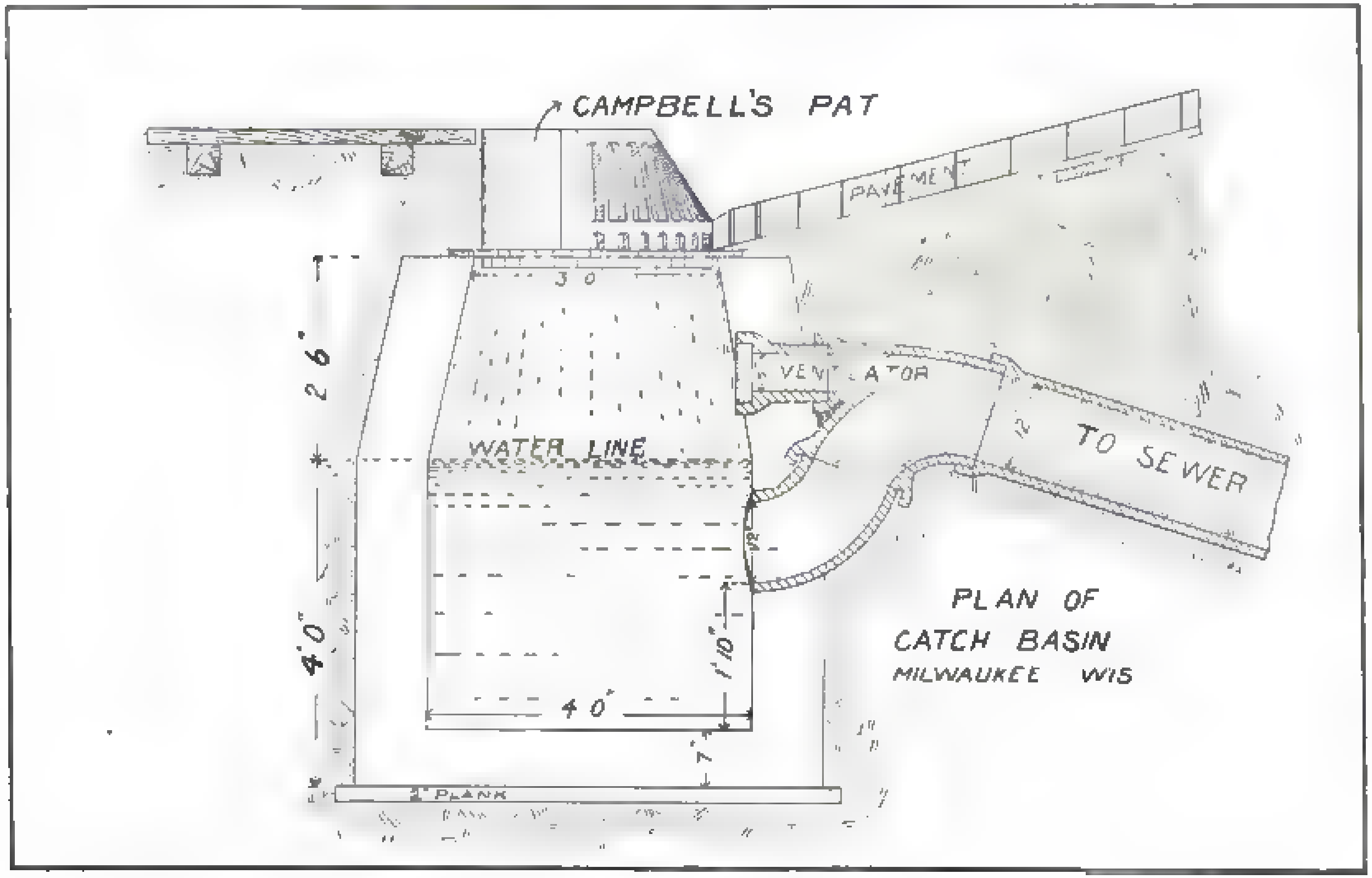


Plan of Catch Basin, Milwaukee, Wis.

to sell the refuse in his quarry at a very small margin over that which it costs to remove the dirt and rubbish. Frequently the rubble and spalls from a granite quarry are equally as good as, or better than, the heavy dimensional stone; or perhaps the stone in the thin beds of a limestone quarry may be preferable to the stone in the heavy beds. This should be known before the stone is contracted for.

If one can obtain stone already broken into pieces of a size suitable to be crushed, the expense of quarrying and blasting is eliminated. If the most desirable stone for road metal can be obtained within the county, it is useless to pay transportation charges on crushed stone from some distant quarry. It has been demonstrated in the eastern states, and in some of the Wisconsin cities, that the most durable stone for macadam pavements is either granite, rhyolite or trap rock. Ledges of this rock occur only in the central and northern parts of the state. The glaciers, however, centuries ago rubbed off and crushed millions of tons of this stone, transported it south and deposited the fragments in a mantle of drift over all of the eastern and southeastern counties of the state. Boulders of granite and trap rock by the millions are piled up in the fence corners of our farms, awaiting the advent of the stone crusher. Granite and trap rock from a quarry could be no better and in the northern counties where both are available, the boulders or field stone are purchased from the farmers at a prices less than it would cost to quarry and break the stone into the dimensions required by the crusher.

With the exception of the southwestern portion of the state, including Grant, La Fayette, Iowa, Richland, Crawford, Vernon, Monroe, Juneau, La Crosse and parts of Buffalo, Trempealeau, Jackson, Wood, Adams, Sauk, Dane and Green counties, the surface of the state is covered with a mantle of drift composed of boulder clay, sand, gravel and boulders. The gravel and boulders consist of all varieties of rock, including granite, porphyry, trap, quartzite and limestone. The glacial drift has in some places been re-worked by stream and lake water. In the eastern and northern portions, adjacent to the

lakes, the surface is covered mainly with clays consisting of reworked glacial drift in which the boulders have often been reduced to gravel, sand and clay.

ADAMS COUNTY.

Adams county is located in the central part of the state. As far as known, the county is underlain entirely with Potsdam sandstone. The land rises to the north and east; the dividing line between Adams and Waushara counties being 200 feet above the Wisconsin river, which bounds Adams county on the west. The larger portion of the county is a level plain from which rise isolated mounds and ridges of sandstone. The level area consists mainly of marshes, prairies and sand plains. The subsoil is very largely sand, derived from the disintegration of the underlying sandstone.

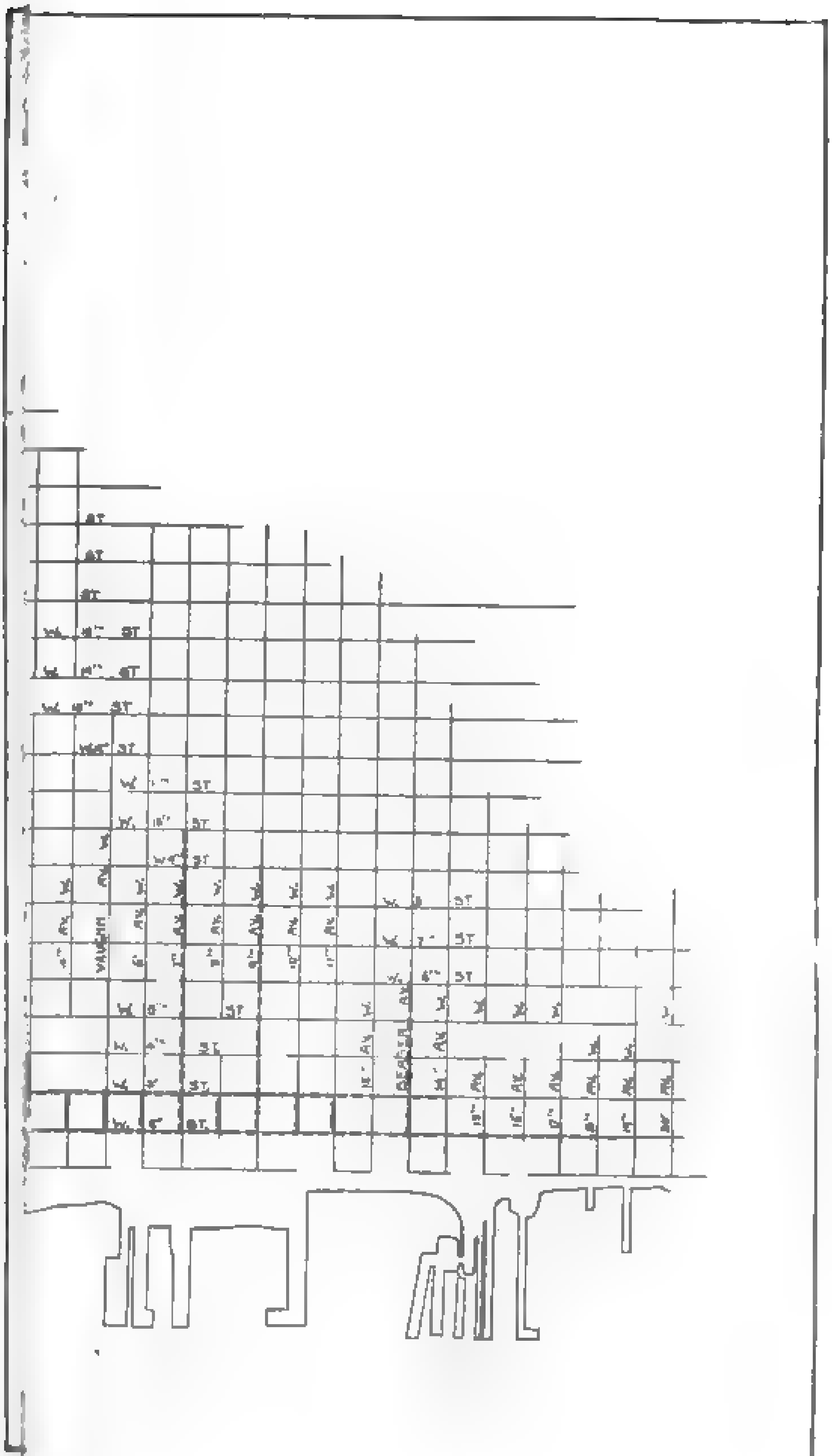
The eastern, western and northern parts of the county are covered with lacustrine and fluviatile deposits, while the southeastern portion is heavily drift covered.

There are only two sources of good road metal in this county. They consist of shaly sandstone layers in the Potsdam formation and the gravel and boulders constituting a part of the glacial deposits in the southeastern part of the county. The scarcity of suitable stone for road construction will undoubtedly retard very greatly the improvement of the roads in this country. Stream gravel and shale or a mixture of clay and sand should be used wherever they are accessible for the temporary improvement of the highways.

ASHLAND COUNTY.

Ashland county is located in the northern part of the state and contains within its borders much stone suitable for the improvement of the highways. The subsoil in this county varies in different localities. Sand, clay and loam are found in various admixtures. The grades of the different roads in various parts of the county differ widely.

Near the lake shore there is an abundance of gravel and clay



which might be used for temporarily improving the highways. The Potsdam sandstone which outcrops in the northern part of the county is unsuitable for paving purposes. The southern part of the county, however, is traversed by a belt of pre-Cambrian rocks, consisting of diabases, gabbros, diorites and granites, which are in many places easily accessible to railway transportation. Besides the outcrops of pre-Cambrian rocks, the county is largely covered with glacial drift consisting of gravel and boulders, which in many places could be used for the improvement of the highways.

The only improved highways in this county are found in the city of Ashland. The pavements in this city are discussed below.

ASHLAND.

(Pop., 13,074.)

Most of the business streets in Ashland have been paved with cedar blocks, all of which have been laid on plank and gravel foundations. The only other pavement constructed is one block, 300 feet, of macadam, which was laid in September, 1900, and built out of blast furnace slag. The following is a list of the streets which have been improved with cedar blocks and the date of their construction.

Name of Street.	Part paved.	Date.
2nd street	7th Ave. W. to Ellis Ave. (7 blocks)	1890
2nd street	Ellis Ave. to 8th Ave. E. (8 blocks)	1893
2nd street	7th Ave. W. to 18th Ave. W	1893
3rd street	14th Ave. W. to 8th Ave. E	1892-7-93
14th street	6 blocks	1892
8th, 7th, 6th, 5th, 4th, 3rd, and 2nd avenues east	1 block each, 7 blocks	1892
6th, 10th, 11th, 12th, 13th, and 14th avenues west	9 blocks	1892
7th avenue west	8 blocks	1891
8th avenue west	1 block	1895
9th avenue west	5 blocks	1892
Ellis avenue	3 blocks	1894

The average width of these pavements between curbs is 46 feet. The average cost of the pavement, including grading, was $1.38 per square yard.

The block which has been macadamized with furnace slag is on 7th avenue west, between 2nd and 3rd streets. The slag used in this construction was obtained in the city and laid in the same manner as an ordinary stone macadam pavement. The thickness of the pavement is 12 inches. The width of the street is 46 feet and the cost of the improvement, including grading and 600 lineal feet of Bedford limestone curbing, was about 55c per square yard.

The sub-soil in this locality is red clay, which provides a very poor foundation for any kind of pavement. Sand and gravel are very scarce, the former of which can be obtained most readily, but at considerable expense, by dredging the lake. There are no quarries in the immediate vicinity of Ashland which contain stone suitable for macadam. For this reason almost any material which it is desired to use in street construction must be shipped in. The use of Bedford limestone for curbing appears somewhat questionable policy. I feel that if stone is to be used, it would be to the advantage of the city to purchase the same from Wisconsin quarries. The best granite and limestone curbing manufactured in Wisconsin has been shown by actual use to be preferable to the sandstone and limestone shipped into Wisconsin from neighboring states.

The curbing which has been used in connection with the cedar block pavements in this city has been mainly granite and is the very best kind of curbing which can be obtained. I think that it would be unfortunate for the city to introduce a cheaper kind of curbing, unless it be portland cement concrete.

Mayor Williams informs me that the railroad rates on vitrified brick from Galesburg, Illinois, or other centers of paving brick manufacture, are so high as to make the construction of this kind of pavement almost prohibitive. However, for the main business thoroughfares this is the most desirable pavement which could be built. For improving the residence streets, granite or trap rock macadam should be used. The city ought

to purchase a trap rock quarry on the Wisconsin Central railroad, erect a small crushing plant and in this way make provision for supplying her future needs.

A systematic plan of construction and maintenance should be formulated, looking to the eventual improvement of all the more important business and residence streets.

BARRON COUNTY.

Barron county is located in the northwestern part of the state. The northeastern and northwestern portions of the county are underlain with pre-Cambrian rocks. The pre-Cambrian rocks of the northwestern portion are largely of the diabase, melaphyre, gabbro and diorite varieties, while those in the northeastern part are mainly quartzite and granite. The southern and western portions of the county are underlain with Potsdam sandstone.

The entire county is covered with glacial drift, through which are scattered numerous boulders and large quantities of gravel, all of which may be used for the temporary improvement of the highways. The stone which is most suitable for road construction is found in the pre-Cambrian rocks in the northeastern and northwestern portions of the county. In these sections there is an inexhaustible supply of rock, which when crushed will supply all the roads in the county with very desirable road metal. The only cities in this county are Rice Lake and Barron, neither of which have yet attempted the construction of permanent pavements.

BARRON.

(Pop., 1,493.)

None of the streets of this city have been paved. The soil is a loamy clay, which when mixed with gravel makes a very fair roadbed. No special gutters have been provided to carry off the surface water.

RICE LAKE.

(Pop., 3,002.)

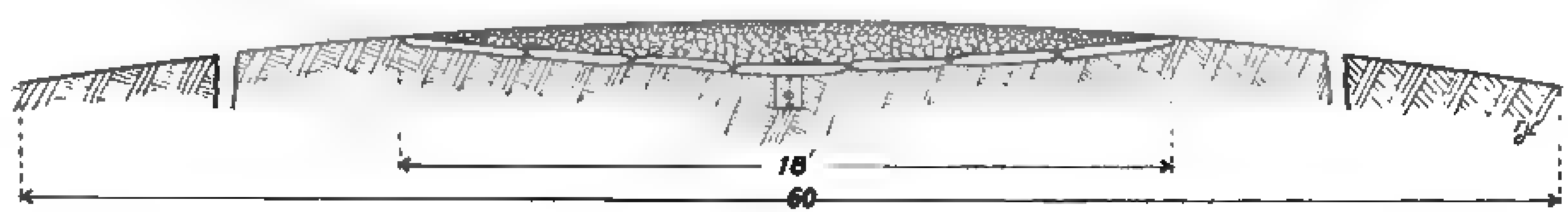
None of the streets of this city have been paved with macadam or any other material. The traffic is very light and the nature of the soil is such that the streets are comparatively hard and smooth throughout most of the year.

Extensive outcrops of a very durable quartzite occur near this city. This stone might be crushed and used to advantage in improving the highways of this and adjacent counties. A sample of this quartzite, collected by Mr. Sewell A. Peterson, was tested in the Survey laboratory. The results of these tests will be found in the table of tests in a subsequent chapter.

BAYFIELD COUNTY.

Bayfield county is located in the northern part of the state bordering on Lake Superior. The land surface in this county is very irregular, giving many of the roads steep and uncertain grades. The northern and eastern portions of the county bordering on Lake Superior are underlain with Potsdam sandstone, over which is frequently found a variable thickness of gravel and clay. The entire county has been glaciated, and in the southern portion especially there occurs a heavy mantle of drift. Underneath the drift, south and west of the Potsdam sandstone, occur rocks belonging to the pre-Cambrian age. These rocks consist mainly of diabase, melaphyre, gabbro, diorite and other varieties commonly known as trap rock. Outcrops of these rocks occur in close proximity to the railroads traversing the county, and should be looked to as the chief source of supply for stone suitable for the construction of macadam pavements.

Glacial gravel is found so abundantly in some parts of the county that it will probably be the only material used for many years in the improvement of the rural highways. The streets of Washburn and Bayfield have been improved mainly by the addition of glacial gravel.



Cross Section of Street, Showing Method of Paving, DePere, Wis.

WASHBURN.

(Pop., 5,178.)

The town of Washburn is provided with large quantities of clay, gravel and sand all of which are used in different proportions in improving the streets and country roads. The streets of Washburn have been improved entirely by using a mixture of gravel and clay. These streets need repairing each year, owing to the washouts caused by heavy rains. It costs, annually, about $30.00 per mile for repairing the roads, and about the same amount for keeping the streets clean.

The streets are graveled for a width of about 30 feet, at a cost of about $800 a mile. In September, 1900, one-fourth of a mile of Bayfield street was improved with clay and gravel at a cost of $200.

BROWN COUNTY.

Brown county is located in the northeastern part of the state at the head of Green Bay. The subsoil in this county is very largely clay or clayey loam, derived from the red lacustrine clays. The county is situated in the area of lacustrine clays, which were deposited during and after glacial times. Limited quantities of gravel occur in different parts of the county,—mainly in the southeastern part, outside of the area of lacustrine clays. Underneath the glacial deposits occur limestones and shales of four different formations. The eastern and southeastern portions of the county are underlain with Niagara limestone. The Hudson River shale and limestone traverse the county in a narrow belt from northeast to southwest. Northwest of the Hudson River shales the county is underlain by a broad belt of Galena limestone, while the Trenton limestone underlies the northwestern part of the county. All of the quarries in this county are in the Galena limestone, and from this formation is obtained all of the local stone used for street improvements. From general observations it appears that the Trenton and Galena formations, especially the latter, furnish the most dur-

able limestone for street paving. However, the different beds in any sedimentary formation vary widely in their suitability for this purpose. In order to know definitely which formation and which beds of any particular formation are best suited for the construction of broken stone pavements would require extensive and careful examinations in the field and tests in the laboratory, none of which we have thus far had time to make. The paved streets in the cities of this county are discussed below.

DE PERE.

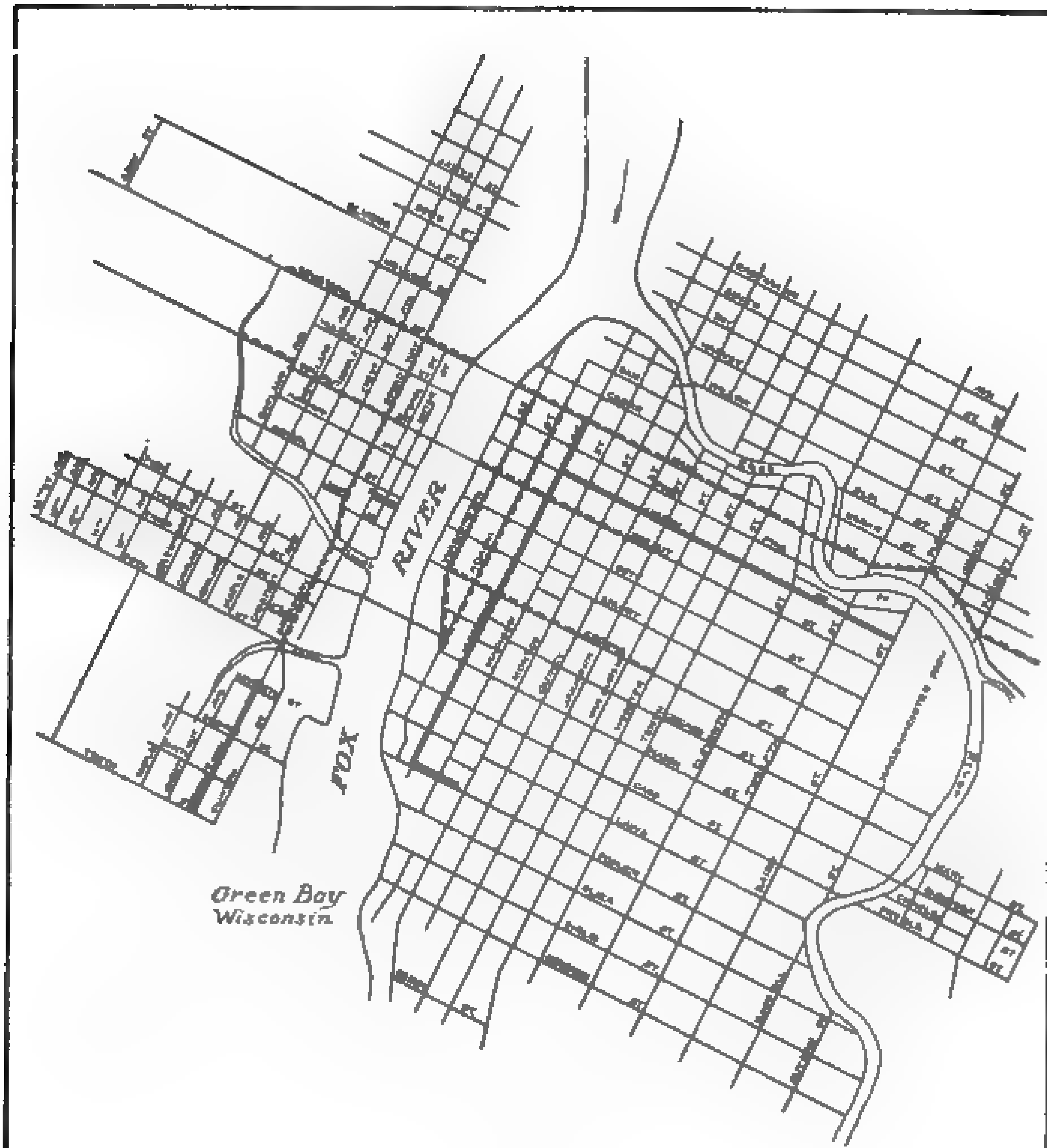
(Pop., 4,038.)

Since 1873 the street improvements in the city of De Pere have consisted mainly of the addition of gravel, hauled upon the streets from the numerous pits near the city. At the present time the city has from 5 to 6 miles of gravel streets, ½ mile of macadam, and 1,500 feet of cedar block, the latter being on the bridge crossing the Fox river.

Dr. W. C. Mailer, to whom I am indebted for this information, says that although the gravel improves somewhat the condition of the streets, it is of little more value than a well kept dirt road. In dry weather the graveled streets are excellent, but in spring and fall they are soft and muddy. This is due to the large amount of clay mixed with the gravel.

In 1893, '94 and '95, Dr. Mailer, as mayor, succeeded in securing the construction of five blocks of macadam. This macadam was constructed on one of the business streets, out of limestone. On account of the heavy clay subsoil in this city it was necessary to lay a foundation of flag stone before adding the crushed stone to the surface. No attempt was made to separate the stone into different sizes and it was spread roughly over the street.

The street improved was one of the worst in the city. It was necessary to remove the dirt from the portion to be paved and lay a drain lengthwise of the street, connecting it with the gutters on either side by cross drains. The pavement was built so that there was a slight grade from the middle of the block toward both ends, to assist the drainage. The earth-bed was



Cedar Block Pavements.

Macadam Pavements.

covered with a layer of flag stone, 3 inches thick, to prevent the crushed stone from sinking into the mucky subsoil underneath. On the top of the flag stones a layer of crushed stone, 9 inches thick at the center and tapering to nothing at the outer edge, was spread. The road was given a slight crown and was allowed to settle and bond in place without rolling. This pavement was 18 feet wide and cost 40c per square yard.

On a number of the other streets crushed stone has been dumped into the soft places and in every instance it has proven itself much superior to the gravel.

The experience of this city in the construction of pavements clearly shows the economy of constructing macadam pavements in preference to using gravel as a temporary expedient.

GREEN BAY.

(Pop., 18,684.)

This city has about six miles of cedar block pavement. On some streets this pavement is in very fair condition, but much of it is worn out. Besides the cedar block pavement, the city has one block of limestone macadam. Limestone from the Duck Creek quarries was used in this pavement. Thus far it has proven very satisfactory and the city is planning to extend it over more of the residence streets.

The main roads leading into the city have been improved, for a width of ten or twelve feet, with a thickness of six or eight inches of broken limestone laid in two courses. The broken stone is spread over the center of the street and left without rolling.

It is very noticable that the improved portion is avoided by the teams except when the remainder of the road is so muddy as to be almost impassable. In time the stone is worn down and packed by the traffic, making a very good roadbed.

BUFFALO COUNTY.

Buffalo county is located in the west central part of the state, on the Mississippi river. The subsoil of this county is largely clay loam. Sandy soils occur along the Mississippi and Trem-

pealeau rivers and sandy loams in the northern part. The surface of the land is rough and hilly, especially near the river. The tops of the hills and ridges are capped with Lower Magnesian limestone, while the valleys and lower portions of the hills and ridges are Potsdam sandstone. The surface of this county is covered with a thin deposit of drift, resulting from the first glacial epoch. The supply of boulders and gravel, however, is not adequate to meet the future demands for materials for road construction. The supply of road metal must be largely obtained from the hard flinty layers of sandstone in the Potsdam formation and the limestone of the Lower Magnesian formation. A careful study should be made of the different ledges of limestone in all parts of the county in order to know definitely which will prove most durable.

The following cities have improved their streets, as indicated below.

DURAND.

(Pop., 1,458.)

None of the streets of this city have been graveled or paved. The subsoil is all sand, except on two streets, where a dark loam is mixed with the sand. The surface water is removed by ditches along the street or by underground tiling. The streets are maintained by a direct tax levy of 2½ mills on about $585,000. Curbing and gutters have been built along only one block in the city.

FOUNTAIN CITY.

(Pop., 1,031.)

None of the streets of this village have been paved. The improvements have consisted entirely of building up the middle of the road by the addition of a clayey gravel.

The subsoil is clay. The surface water is removed by open gutters built out of flag stone.

MONDOVI.

(Pop., 1,208.)

None of the streets of this village have been paved, there being no gravel or suitable stone for macadam near at hand. No gutters or curb being laid, the surface water flows off from the street in the easiest manner possible.

BURNETT COUNTY.

Burnett county is located in the northwestern part of the state, bordering on the St. Croix River. Along the river and for some distance back the land is broken and hilly. The county as a whole is rolling, and in some parts has the pitted surface so characteristic of morainal topography.

The soils of this county are, as a rule, very sandy, bordering on what is commonly known as sandy loam. In the northwestern and southern parts of the county, and also in small areas elsewhere, the soil is a light variety of clayey loam. In the western part of the county occur occasional areas of humus soil, composed mostly of muck and peat.

The surface of the entire county has been modified by glaciation. In the western and southwestern parts occur heavy dedeposits of glacial drift. A medial moraine has been traced across the county, running in a northeast-southwest direction. The glacial drift, of which this is a part, contains extensive deposits of gravel which may be used to advantage in the improvement of the highways.

The western part of the county is underlain with sandstone of the Potsdam formation. The northwest corner, as well as all of the southeast portion of the country, is underlaid with pre-Cambrian rocks of the Keweenawan formation. These rocks consist of diabase, melaphyre, diorite and other varieties of rock commonly known as trap. They constitute the very choicest stone for building macadam pavements. The supply is practically exhaustless, and in time the county ought to have some of the best highways in the state.

CALUMET COUNTY.

Calumet county is located in the east central part of the state, bordering on Lake Winnebago. Adjacent to the lake, the topography is somewhat abrupt and rugged, especially in the northern part. In the eastern part the topography is typical for the lacustrine clay area bordering on the great lakes in this state. It is rolling and undulating, but contains no very pronounced hills or ridges.

The soils are very largely clayey loams derived from the regular lacustrine clays. Some of these clays, especially in the southern part, are very heavy. The central, southern and eastern parts of the county contain somewhat extensive areas of humus soil, composed largely of muck and peat.

A large part of this county is underlain with Niagara limestone which outcrops in numerous places along the tributaries to the Sheboygan and Manitowoc rivers. In the western part of the county, next to Lake Winnebago, there occurs a strip of land which is underlain with Hudson River shale, while the northwestern part of the county is underlain with Galena and Trenton limestone. This county contains numerous quarries located at High Cliff, Stockbridge, Brillion, Hayton and other places. The limestone occurring in the Hudson River formation is, as a rule, too soft for use as a road metal. The limestone from the Trenton and Galena formations, gives evidence of being most suitable for the construction of pavements. Near the eastern part of Calumet county occur numerous deposits of glacial boulders, consisting of granitic and trap rocks, which constitute the very best stone for paving purposes. Both the Chicago, Milwaukee and St. Paul and the Wisconsin Central railways pass through these boulder trains and it is my impression that crushers located at these points could supply a part of Calumet county with stone which is far superior to the limestone now being quarried and used.

Cedar Block Pavements.

CHIPPEWA COUNTY.

Chippewa county is located in the west central part of the state. The surface of the county is rolling, and in some sections hilly, especially along the Chippewa river and its tributaries. The soils are mainly sandy loams. In fact, almost the entire southwestern part of the county is covered with sandy loam. Clayey loams occur in the southeastern, northern and northeastern portions of the county, while irregular areas of humus soils, composed mostly of muck and peat, are scattered through the northern and central parts of the county. The entire surface of the county has been glaciated, the two northern tiers of townships being within the terminal morainal area of the last glacial epoch. The location of this moraine in the northern part of the county gives the surface a rough and somewhat rugged contour. The moraine consists mainly of boulder clay, sand and gravel distributed in irregular ridges and hills. The boulders and gravel, when properly selected, constitute an excellent road metal.

The western part of the county is underlain with sandstone of the Potsdam formation. Certain horizons of this formation consist of interlaminated clay and thin sandstone layers commonly known as shale. When broken up and thoroughly mixed, the shales have been found to be an excellent material for the improvement of sandy roads. These shaley beds ought to be traced throughout the county and located so as to be made accessible for the improvement of the highways. The eastern part of the county is underlain mainly with pre-Cambrian rocks of the granitic and metamorphic varieties. In the north central part of the county there occur extensive areas of quartzite and gneissoid rocks which outcrop in numerous places along the river channels at Chippewa Falls and elsewhere, furnishing an inexhaustible supply of excellent road metal.

CHIPPEWA FALLS.

(Pop., 8,094.)

Up to the 1st of January, 1901, Chippewa Falls had approximately 1½ miles of cedar block pavement. The first of

these pavements was laid in 1892 and the last in 1893. On the following page is a list of the streets paved, with miscellaneous information relative to their construction.

Mr. David Kirk, formerly city engineer, to whom I am indebted for this information, says that in opening the streets to lay or repair service pipes, cedar blocks can never be replaced in good condition. They are not uniform in size or shape and must be refitted to the space opened up. He has observed further that cedar blocks wear very unequally, and on account of their capacity to absorb water are not hygienic. In dry weather the blocks are usually loose and in wet weather they swell to such an extent as to frequently displace the curb stones. So unsatisfactory has this pavement proven to the people of this city that it is no wonder that they are now unqualifiedly opposed to all kinds of wooden pavements.

Mr. Kirk says that pine planks make a very poor foundation for a pavement and that no pavement whether wood, brick or stone should be laid on anything but concrete six inches or more in thickness.

This is certainly a safe basis on which to work, although it frequently multiplies unnecessarily the expense. It frequently happens that gravel, sand or broken stone serves equally well the purpose of a concrete foundation. Mr. Kirk's suggestion that pine planks properly treated and laid on concrete ought to constitute a good pavement is worthy of consideration. I think it might have been better to suggest tamarack in place of pine. The use of properly creosoted blocks of tamarack uniform in shape and laid on a concrete foundation would certainly make an excellent foundation for cities the size of Chippewa Falls.

Apparently no attention has been given to the building of macadm pavements. There is an unlimited supply of granite rocks within the city limits and I believe that this pavement ought not to be overlooked especially in connection with the improvement of the residence streets.

Chippewa Falls.

Name of Street.	Part paved, macadamized, etc.	Date.	MATERIALS USED IN CONSTRUCTION.				Where material was obtained.	Average width of street between curbs.	Cost of construction per square yard, exclusive of curb, gutter and underground pipes.
			Foundation.		*Surface.*				
			Kind.	Thickness.	Kind.	Thickness.			
Bridge........	From Elm to River........	1892	Pine plank..	2 in.	Cedar block.	6 in.	Chippewa Co...	42 feet.	$1.00
Bay.........	From Grand Ave. to River	1893	Pine plank..	2 in.	Cedar block..	6 in.	Chippewa Co...	42 feet.	1.00
Grand avenue.	From Bay to Bridge.......	1893	Pine plank...	2 in.	Cedar block..	6 in.	Chippewa Co...	42 feet.	1.00
Central.......	From Bay to Bridge......	1893	Pine plank...	2 in.	Cedar block..	6 in.	Chippewa Co...	42 feet.	1.00
Spring.........	From Bay to Bridge.......	1893	Pine plank...	2 in.	Cedar block..	6 in.	Chippewa Co...	42 feet.	1.00
Central.......	From Bridge to Creek.....	1893	Pine plank...	2 in.	Cedar block..	6 in.	Chippewa Co...	42 feet.	1.00

CLARK COUNTY.

Clark county is located in the west central part of the state. The surface is rolling except adjacent to the Black river and its tributaries where the hills are often steep and abrupt. In the southwestern part of the county and along the Black river fifteen or twenty miles north of Neillsville, the surface is covered with sandy soils. The entire southern and west central portions, as well as narrow belts along the upper tributaries of the Black river, are covered with sandy loams. A greater part of the nothern and eastern sections of the county are covered with the lighter varieties of clayey loams.

The county is covered with a thin mantle of drift left by one of the earlier glacial epochs. The drift deposits contain some gravel and numerous boulders.

The northern half of the county and a narrow belt along the Black river are underlain with rocks belonging to the pre-Cambrian formations. These rocks consist mainly of granite and gneiss, although trap rocks have been noted in a few localities. The granitic rocks outcrop in numerous places throughout the northern part of the county, providing an inexhaustible supply of excellent stone for road metal. The southern part of the county is mainly underlain with sandstone of the Potsdam formation. In the vicinity of Neillsville and elsewhere occur outcrops of arenaceous shale which has been used quite generally for improving the country roads. This so-called shale is similar to that which occurs in Chippewa county and is to all appearances an excellent material for the temporary improvement of the highways.

NEILLSVILLE.

(Pop., 2,104.)

Grading and gravelling are the only street improvements which have been made in this city. There is an abundance of granite, almost within the city limits, which if crushed would make excellent macadam pavements. There are great quantities of boulders, scattered over the fields in this part of the state,

all of which could be used to advantage for macadamizing roads and streets.

On the road north from Neillsville, toward Loyal, there are numerous outcrops of interbedded sandstone and clay. This material is similar to the so called shale which is used at Eau Claire and Merillan, and ought to make equally as good a road bed. This shale was observed at different points along the road for a distance of four or five miles. It should be quarried and used much more extensively than it is for improving the rural highways.

GREENWOOD.

(Pop., 708.)

The only improvements which have been made to the streets in Greenwood has been through the addition of gravel which is plentiful in that region. The subsoil is clay, and with the addition of several inches of gravel the streets are kept in good condition. Main street has been gravelled for its entire length of over a half a mile and four blocks of as many intersecting streets have also been improved in this way.

The elevation of the city with its natural drainage into Black river and Roock creek, makes the question of surface drainage very easily disposed of.

THORP.

(Pop., 838.)

This village has given very little attention to street improvements. Four blocks of Washington street and two blocks of Main street have been covered with about six inches of gravel. The gutters on these streets are built out of flag stone and the street is given enough crown to remove the surface water.

The gravel which has been used on these streets occurs in the bed of the river, about three miles west of the village. The subsoil at this place is a clay loam.

COLUMBIA COUNTY.

Columbia county is located in the south central part of the state. Except immediately adjacent to the Wisconsin, Baraboo and Fox rivers, the surface of the land is broken by very few hills or ridges of importance. The glacial drift which covers a large part of the county has given the topography a generally rolling and slightly hilly aspect.

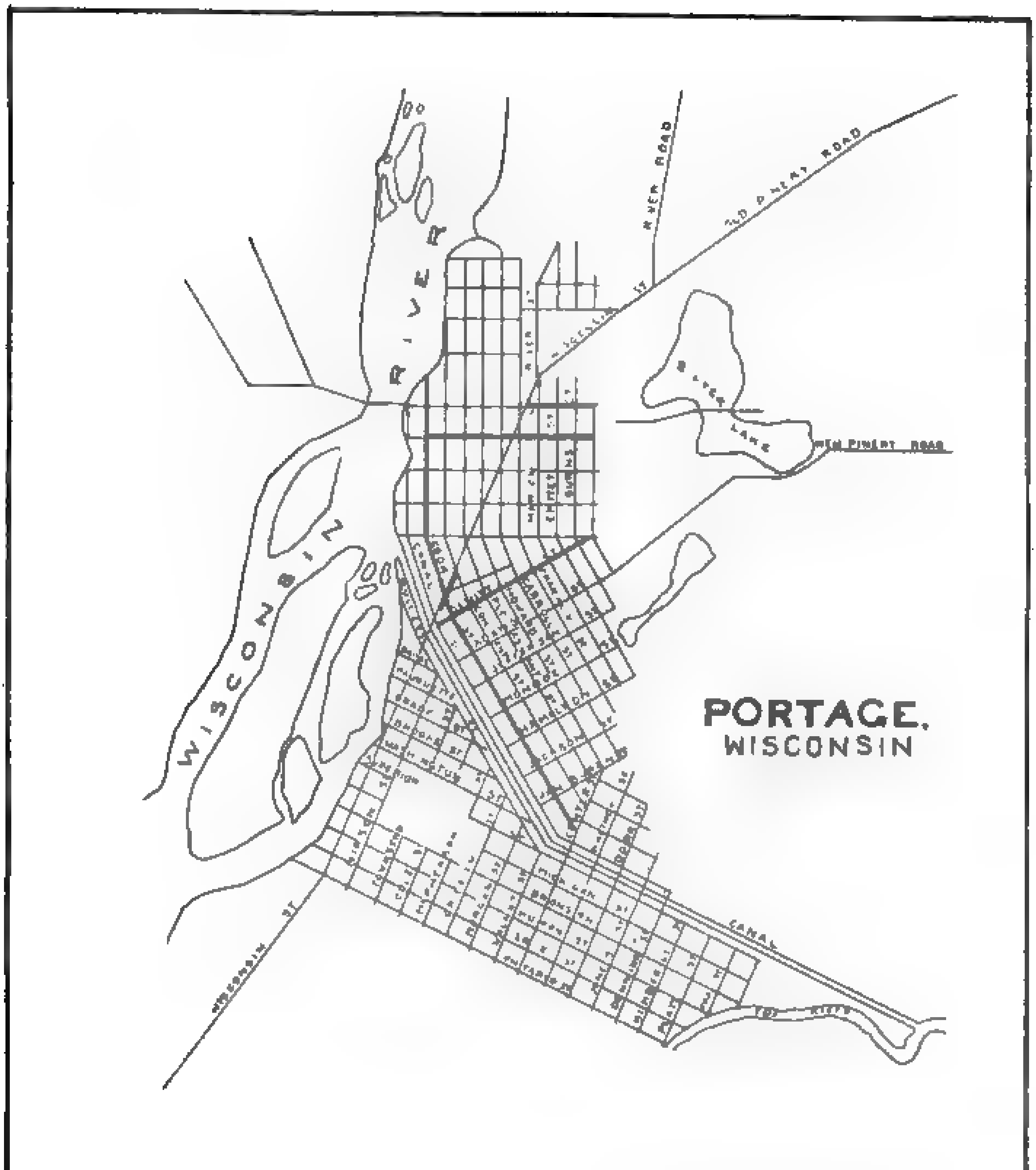
The soil in the northwestern part of the county is mainly of a sandy nature, while that in the eastern and southeastern portions consists of clay and prairie loams. Numerous small areas of humus, composed mostly of muck and peat, occur through the northwestern part of the county along the Wisconsin and Fox rivers and their tributaries. In the southwestern and northwestern corners of the county are heavy deposits of drift, composed of gravel and boulder clay. Through the southern and eastern portions are somewhat extensive deposits of drift also containing boulder clay and gravel. The gravel and boulders furnish an excellent source of supply of stone for road construction, one of the best in the country.

The northwestern portion of the county is largely underlain with sandstone of the Potsdam formation. The eastern and southeastern portions are underlain with limestone of the Lower Magnesian and Trenton formations and sandstone of the St. Peters formation. The Trenton and Lower Magnesian limestones, when properly selected, may be used to advantage in constructing broken stone pavements. The sandstone of the Potsdam and St. Peters formations, in this region, is not desirable for this purpose. In the north central part of the county occurs a hill composed of porphyry which ought to supply the immediate locality with an abundance of excellent road material.

PORTAGE.

(Pop., 5,459.)

The following is a list of the improved streets of Portage up to January 1st, 1901.



Granite Macadam Pavements.

Brick Pavements.

Portage.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction. — *Foundation.* Kind.	*Foundation.* Thickness	*Surface.* Kind.	*Surface.* Thickness.	Where material was obtained.	Av. width of street between curbs.	Cost of construction per square yard exclusive of curb, gutter and underground pipes.
Mac........	2,100 feet..........	Oct., 1899	Sand.	Several ft.	Crushed granite.	3 to 6 in.	Montello.	36 ft.	
Wisconsin.	600 ft. brick...........	'93–'94	Sand.	Several ft.	Crushed granite.	3 to 6 in.	Montello granite.	42 ft.	Brick about $1.00 per sq. yd.
	5,000 ft. broken stone.	Brick in '98	Sand.	Several ft.	Crushed granite.	3 to 6 in.	Bloomington, Ill.	42 ft.	Broken stone $1.55 per cu. yd.
Cook	700 feet................	1898	Sand.	Several ft.	Vitrified brick...	4 in.	Bloomington, Ill.	42 ft.	$1.00 per sq. yd.
Cook	5,000 feet.	1895	Sand.	Several ft.	Crushed granite.	3 to 6 in.	Montello, Wis...	42 ft.	$1.55 per cu. yd. delivered.
Dewitt	3,000 feet	1895	Sand.	Several ft.	Crushed granite.	3 to 6 in.	Montello, Wis...	42 ft.	$1.55 per cu. yd. delivered.
Dewitt	1,000 feet	1898	Sand.	Several ft	Vitrified brick...	4 in.	Bloomington, Ill.	42 ft.	$1.00 per sq. yd.
Oneida. ...	1,000 feet..	1895	Sand.	Several ft.	Crushed granite.	3 to 6 in.	Montello, Wis. ..	42 ft.	$1.55 per cu. yd. delivered.
Cass.......	2,000 feet.	1895	Sand.	Several ft.	Crushed granite.	3 to 6 in.	Montello, Wis. .	42 ft.	$1.55 per cu. yd. delivered.

The subsoil in this vicinity is practically all sand. The pavements consist of brick on the business and granite macadam on the residence streets. In 1882 and 1884 about a half mile of cedar block pavement was built which in 1898 was replaced with vitrified brick. About three and a half miles of macadam have been built on the residence streets.

The brick pavement consists of a single layer of brick laid on edge on a sand foundation, and having the joints filled with sand. This pavement is on the principal business streets of the city, which are really subject only to light business traffic. The pavement has been down about three years and shows very little evidence of wear.

The curbing is obtained from various places. Beaver Dam and Menomonie Falls limestone, Kilbourn City sandstone, and cement concrete are all used in different parts of the city. The cement concrete is made in flat slabs resembling stone curbing and is set in the same manner. Insufficient care has been taken in setting the curbing and in many places it is out of line. The macadam pavement consists of a thickness of about five inches of medium sized crushed Montello granite the interstices of which are filled with fine screenings. The pavement is rolled with a light horse roller both before and after the screenings are added. Most of the pavements are laid without special gutters and very little attention has been paid to giving the street a uniform crown. The pavements are cleaned and repaired at irregular intervals and without any special system.

The property owners pay for the stone used on the streets, and the city pays for constructing the pavement. The construction of the pavements is not in full charge of the city engineer.

Mr. C. E. Corning, to whom I am indebted for the above information, says, "No permanent surfacing should be done until the grading has been completed. On sandy streets where clay is easily obtainable, a clay track and a sand track built side by side will fit both wet and dry weather. Broken stone pavements built for heavy traffic should be ten inches thick." Mr. Corning further observes that road construction and maintenance should be in charge of the city engineer. This is cer-

tainly proper, and the sooner the municipalities of the state recognize this fact the less will they lose through the wrong application of funds set apart for street construction and maintenance.

COLUMBUS.

(Pop., 2,349.)

The business streets of Columbus are paved with broken stone quarried from a limestone ledge owned by the city. The city owns a crusher and hires a traction engine to run it at a cost of about $8.00 per day. The city then pays 60 cents per yard for having the stone hauled onto the streets and pays men $1.25 per day to spread the same. No attempt has been made to systematize the street improvement work. Such repairs or improvements as are necessary are made during the early summer months and continued until the tax levy is exhausted.

The city clerk informs me that the crushed limestone which they have used is very unsatisfactory. His experience shows that it grinds into mud during wet weather and is very dusty during dry weather. The city spends about $3,000 every season for road work, and if this amount could be applied systematically the citizens might soon enjoy some excellent pavements. The thing which is needed in this, as in a great many other cities, is a proper administration of the funds available. This would mean the use of proper materials and the inauguration of a system of maintenance by which the pavements could always be kept in good condition.

CRAWFORD COUNTY.

Crawford county is located in the southwestern part of the state on the Mississippi and Wisconsin rivers. The portion of the state in which this county is located is known as the driftless area. The land is broken up into ridges and hills, having the rough, irregular topography characteristic of river erosion. The soil in the western part along the Mississippi river and in the southern part along the Wisconsin river is mainly a sandy loam. The central part of the county including that portion

between the Kickapoo river and the Mississippi valley, is covered with a light variety of clayey loam. A medium variety of clayey loam covers a large part of the surface of the county east of the Kickapoo river.

With the exception of the river valleys, the county is mainly underlain with either Lower Magnesian, Trenton or Galena limestone. Some of the higher portions of the land in the northwestern and eastern parts of the county are capped with St. Peters sandstone. From the bottom of the river valleys to the tops of the ridges which constitute the divides, there are exposed rocks of the Potsdam, Lower Magnesian, St. Peters, Trenton and Galena formations. Along the rivers there frequently occur banks of flint gravel, which, combined with the limestone which may be obtained from the quarries, constitutes the best local material for the construction of broken stone pavements. The different beds of limestone in this region should be carefully examined both in the field and laboratory in order to ascertain the most durable stone accessible for road construction in different parts of the county.

PRAIRIE DU CHIEN.

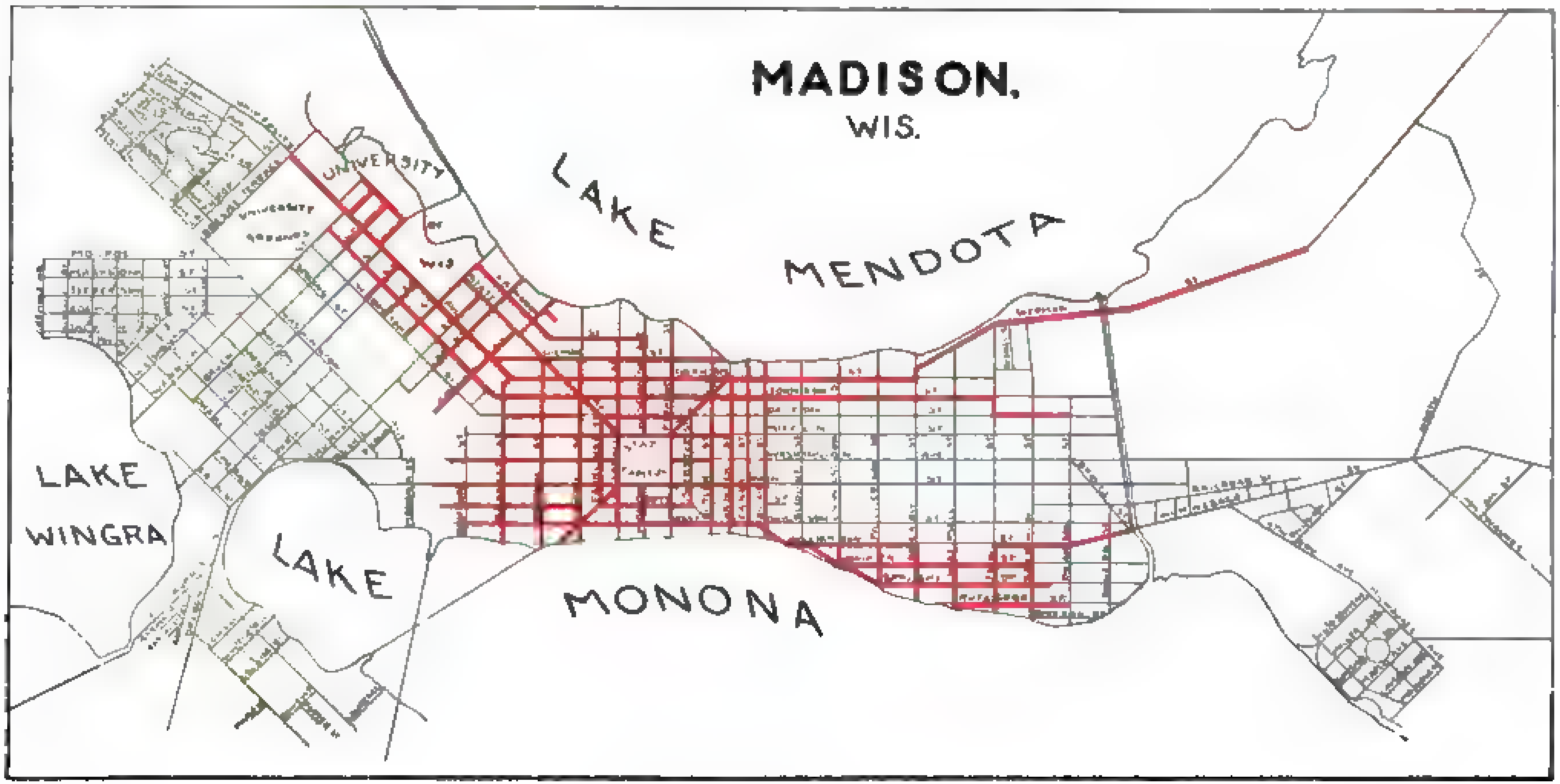
(Pop., 3,232.)

The subsoil in this city is mainly a sandy loam and is well suited for the construction of any pavement. Some of the streets have been improved by spreading several inches of clam shells over their surfaces and covering them with soil.

Along the bluffs east of the city occur interbedded layers of sandstone and clay similar to the shale which is found at Eau Claire and in other parts of the state. This material has been used to improve a number of the sandy roads leading into the city. As has been previously stated, this shale is an excellent material for making temporary improvements to rural highways.

DANE COUNTY.

Dane county is located in the south central part of the state. With the exception of about nine townships in the western and southwestern portions, this county is within the glaciated region.



Macadam Pavements. Mainly Limestone.

The western part, which is in the driftless area, has a rough topography, resulting from stream erosion. That portion which has been glaciated is rolling and hilly, as a result of the accumulations of drift which are strewn over the surface. The soils in this county consist mainly of clayey and prairie loams. A broad belt of sandy loam traverses the western part of the county, while the eastern part contains irregular areas of humus soils composed mostly of muck and peat.

The glacial drift in this county comprises a portion of the terminal moraine which is made up of boulder clay, sand and gravel. The gravel and boulders of trap and granite rocks, which are found very generally in the eastern part of the county, constitute a source of excellent material for road construction.

The central part of the county is underlain with sandstone of the Potsdam formation and the northern part mainly with Lower Magnesian limestone. St. Peters sandstone and Trenton and Galena limestones occur in the eastern and southern portions of the county. Their distribution is very irregular, all of them frequently being found along the bluffs in the southwestern part of the county. The stone from the hard beds of the Lower Magnesian formation is used most extensively in building broken stone pavements. Much of the stone from the different formations is unsuitable for street paving and the utmost care should be exercised in selecting that which will prove most durable.

MADISON.

(Pop., 19,164.)

The city of Madison commenced the construction of macadam pavements sometime prior to the year 1880, at which time two and a half miles of broken stone pavements had been built. Each year since then, with the exception of 1885, additional streets have been macadamized, until, at the present time, the city has something over twenty-five miles of macadamized streets. Until 1889, the broken stone pavements were paid for out of the general fund. Under this plan, the city constructed

5.67 miles of macadam pavements. In 1889 the city changed the method of paying for street improvements, assessing the cost directly against the abutting property. Under this law about nineteen miles of streets have been macadamized. During the last eight years, the city has built about ten miles of macadam pavements. During this same period, some of the streets have been macadamized once, and others have been macadamized twice.

Between 1889 and 1900 the property holders paid in the neighborhood of $236,000 for macadam pavements. Not considering the width of the pavement, the cost has been at an average rate of $14,700 per mile.

With two or three exceptions, the city has experimented with no other material except the limestone quarried west of the city. The only other material which has been used is a limited quantity of quartzite from the Baraboo bluffs and a few carloads of granite from the central part of the state. The experiments with quartzite were not satisfactory to the city engineer on account of the difficulty experienced in bonding the stone. No attempt was made to use other materials for bonding purposes, and the stone was unreservedly condemned as being unsuitable for macadam pavements. Not only was the quartzite condemned but granite and trap rock, which are proving to be so well suited for macadam in other parts of the state, were likewise rejected. Quartzite cannot be placed in the same category with granite and trap rock when used for macadam pavements. Many of the varieties of granite and trap rock can be used without the addition of any bonding material except the fine dust obtained through the crushing of these stone, but the quartzite must be used in connection with limestone gravel or screenings.

Prior to 1889, the stone used for macadamizing was hauled by team from the quarries and broken by hand on the streets where used. In 1889 the city purchased a crusher and the following year came into possession of the quarry which it now owns. All the work of construction is under the direct supervision of the city engineer who makes out plans and specifications

Typical Unpaved Street. Murray Street, from West Johnson, Looking North, Madison, Wis.
Since this photograph was taken the street has been paved.

and approves or rejects the work when completed. In some instances the city has accepted pavements before they have been completed, thereby establishing a very bad precedent. The Massachusetts highway commission will not accept a pavement until it has been used by the public for at least two months.

The cost of constructing the macadam pavements has varied during the different years. The cost has depended in part upon the street which was macadamized, but mainly upon the thickness of the pavement and the kind of gutters constructed. Exclusive of gutters, catch basins, etc., the cost of macadamizing West Washington avenue was about 50 cents per square yard. The total cost of macadamizing this street was $16,199.88, of which about $9,156 was expended for the macadam; $4,627 for cement gutters, and about $2,056 for miscellaneous work.

Referring to the methods of construction which have been employed on the streets of Madison, there are several changes which I believe might with safety be made.*

First.—It is thought that the macadam pavement on some of the streets is unnecessarily wide. I believe that the system of parking the streets should be made more general and the park areas widened at the expense of the macadam. Madison may justly be proud of the width of her streets, many of which may be made very beautiful if the plan of increasing the park areas should be indulged in. Lessening the width of the macadam would in no way hamper or congest the traffic on the residence streets of the city, while the original cost of construction and the cost of maintenance would be very greatly lessened.

Second.—At the present time all the streets are macadamized with about the same thickness of macadam in all their parts without regard to the location of the street or the character of the sub-soil. The only difference in the methods employed on different streets is the policy of using a telford foundation where the land is low and marshy. The use of telford in these places is certainly commendable.

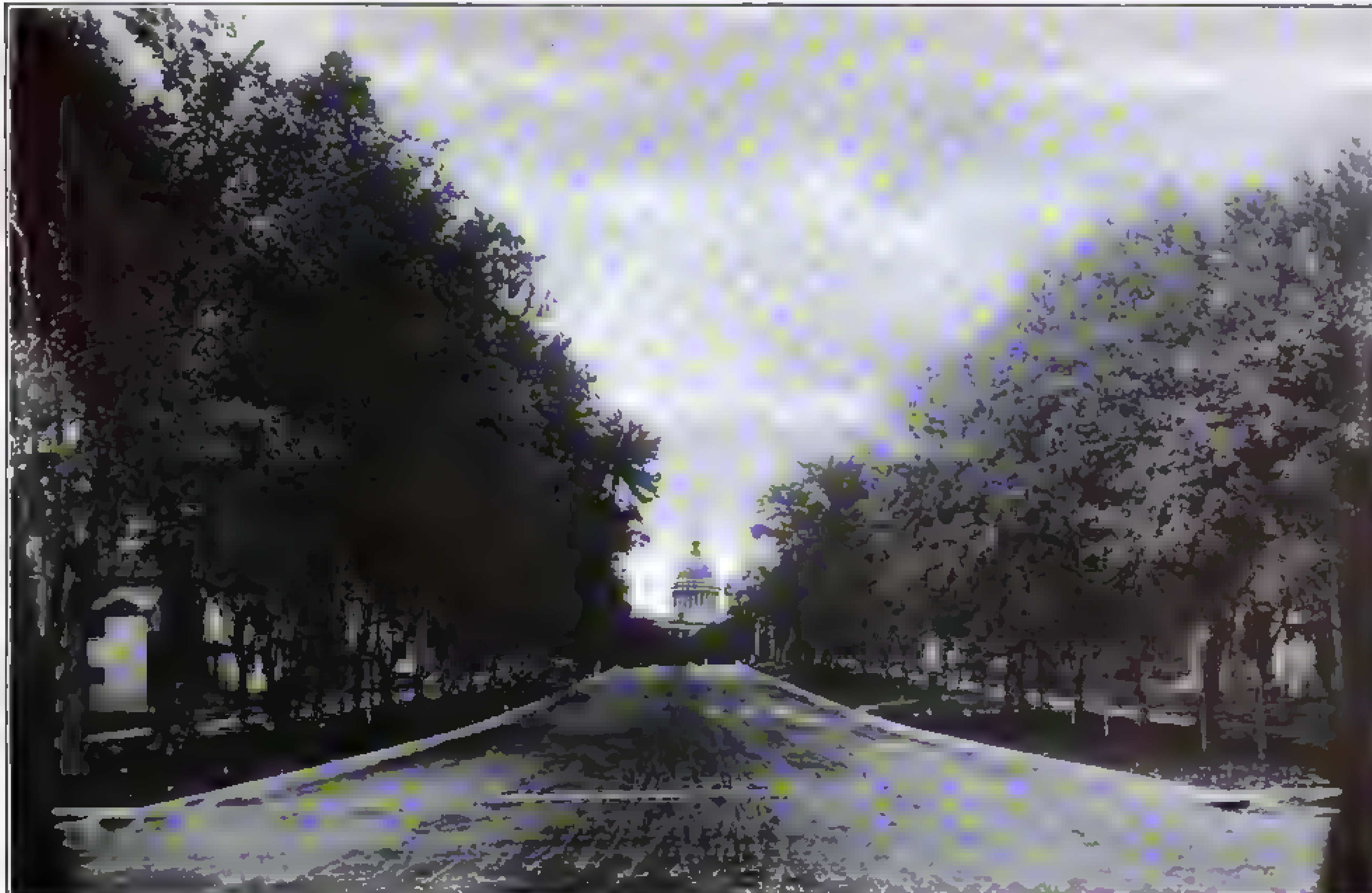
*Since writing this part of the report, most of these changes in policy have been made by the authorities in charge of street construction in the city of Madison.

I do not believe, however, that all of the streets should be covered with the same thickness of broken stone. In many places a thickness of ten or twelve inches is unnecessary and entails upon property holders an undue expense. The telford pavement on West Washington avenue was made the same thickness on the top of the hill as it was on the low ground near the railroad tracks. It is evident, however, that the avenue between Carroll and Henry streets did not require a telford foundation. Further, if nine inches of macadam is considered sufficient for the soft ground between Bassett and the Illinois Central Railway tracks, it is reasonable to suppose that a less thickness would be sufficient between Carroll and Henry streets. The thickness of a macadam pavement should be regulated according to the location of the street, the kind of subsoil and the amount of traffic.

Third.—The screenings with which a macadam pavement is finished should be spread to a thickness of at least one half inch. This is not usually done in constructing Madison pavements. Sufficient screenings should be used to fill the interstices in the layers of coarse, broken stone, and leave a thin layer covering the surface.

Fourth.—Since the city adopted the cement combined curb and gutter, it has been the policy to construct the curb and gutter before laying the macadam. This order should be reversed if it is expected to obtain the best results. It is a fundamental principle in street construction, taught by our most experienced engineers, that gutters should always be constructed after a macadam pavement is completed.

The street should not be made to conform to the line of the gutters, but the gutters should be made to conform to the street. It has been found that the weight of the roller as it passes over the layers of broken stone frequently moves the curb and gutter out of place. In order to avoid this danger, the roller is now kept ten or twelve inches away from the gutter with the result that there is usually a loose strip of macadam along each side of the pavement next to the gutter. This uncompacted strip of broken stone eventually settles, leaving the gutters above the



Limestone Macadam Pavement. New. West Washington Avenue, Looking Northeast from Broom Street, Madison, Wis.

margin of the pavement. Part of the water which flows off of the street follows the gutter, and the other part flows off in the depressed portion of the pavement adjacent to the gutter.

Fifth.—The gutters are constructed of practically the same width on all streets regardless of the amount of surface water which they are called upon to carry off. The width of the gutter is in many cases inadequate to carry off the surface water which flows into it. This results in injury to the pavement through overflow during heavy storms.

The gutters should be laid at least two inches lower than the macadam pavement to provide for settling and future wear.

The above matters deal almost entirely with the methods for keeping the pavement dry. In order to maintain a pavement in good condition, we must provide, first, for the rapid removal of the water from the surface, and second for the construction of the pavement so as to prevent the absorption of water.

Up to the present time, the macadam pavements of Madison have been built mainly out of limestone, with an occasional admixture of sandstone. Pure limestone is composed of calcite, which in the scale of hardness of 10, to which all minerals are referred, has a value of 3. It has a strength of probably 10,000 to 20,000 pounds to the square inch. When limestone is broken or ground, it is quickly reduced to a powder, so fine that the lightest breeze will lift it into the air. The stone which has been used in Madison is a dolomite rather than a limestone and contains a small percentage of clay and iron. This combination of lime, clay and iron, when reduced to a powder, makes a very plastic, sticky mass when wet. It does not pack, but is lifted by the hoofs of horses and wagon wheels. When dry, it forms dust that is lifted into the air by the slightest breeze. In contrast to this rock, attention should be directed to granite and trap rock out of which fine dust or mud are much more difficult to produce. Granite consists mainly of three minerals which have an average hardness of 7 and a crushing strength of from 20,000 to 40,000 pounds per square inch. When these minerals are broken or ground, they form a coarse powder which when wet does not have the plasticity or stickiness of that

formed out of limestone. On account of the coarseness of the powder and lack of stickiness there is less dust in summer and less mud in the spring and fall on a granite macadam pavement than on a pavement constructed out of limestone.

With a surface layer of granite laid on a foundation of limestone, there would be little or no dust or mud compared with that which at the present time makes the streets of Madison at certain seasons almost unbearable.

The pavements in the city of Madison have suffered greatly from the laying of pipes by the water department and gas company. No sooner has the roller left a street than the gas company or the water department often makes its appearance with pick and shovel to dig it up. The careless replacing of macadam after the excavation has once been made has hastened the rapid deterioration of the pavements.

Madison should adopt a permanent policy of street maintenance rather than continue the present plan of fall and spring cleaning. The system of cleaning and repairing, by which a street is allowed to wear until reconstruction is necessary, should be entirely done away with. The section system, such as is employed by many eastern cities and railroad corporations, should be adopted in Madison. Under this plan, the city would be divided into districts and each district would be under the direct supervision of one man who would be responsible to the people of that district for the care of the streets. The expense of this system could not exceed very greatly that which the present method costs and from which there has been but imperfect results.

DODGE COUNTY.

Dodge county is located in the southeastern part of the state. The surface of the land is rolling, such as is typical for the glaciated region. The soils are mainly the lighter and heavier clay loams, the latter occurring mainly in the southwestern portions of the county. Numerous small areas of humus soils, composed largely of muck and peat, are found in different parts of the county.

The glacial deposits contain great quantities of gravel which is used very generally for the improvement of the rural highways. This gravel is mainly limestone which frequently contains enough clay to serve as a bonding constituent. Granite and trap rock boulders, which are strewn in large numbers over the higher portions of the county, might be crushed and used to advantage for road construction.

The eastern part of this county is underlain with Niagara limestone. West of the Niagara limestone occur, in succession, Hudson River shale, Galena limestone, Trenton limestone, St. Peters sandstone and Lower Magnesian limestone. Of the different limestone formations the Trenton and Galena undoubtedly furnish the best stone for macadam pavements. In the southwestern part of the county, there occur several outcrops of pre-Cambrian quartzite. This stone is almost equal in hardness to granite and in conjunction with the limestone might be used to advantage in the construction of macadam pavements.

Dodge county is supplied with an abundance of good material for road construction. It is very important, however, that the parties using limestone should select only that which is most durable. The best stone in the quarry is none too good for street paving.

BEAVER DAM.

(Pop., 5,128.)

The following is a summary of the improved streets in Beaver Dam.

Beaver Dam.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction. *Foundation.* Kind	*Foundation.* Thickness.	*Surface.* Kind.	*Surface.* Thickness.	Where material was obtained.	Average width of street between curbs.	Cost of crushed stone.
So. Spring	84.5 rods.	1899	Clay and gravel.	6 to 18 in	Crushed limestone.	6 to 12 in.	1¾ miles from city.	50 ft. on business sts. 18 ft. on residence streets.	$1.75 per cu. yd.
R. R. Ave. and Division	72 72 rods	1899							
Washington	80 rods.	1899							
Henry	80 rods.	1899							
Center	160 rods.	1899							
So. Spring	80 rods.	1899							
Beaver	160 rods.	1899							
Division	80 rods.	1899							
Burnett	240 rods.	1899							
Front	45 5 rods.	1892			Crushed limestone.	12 in.		46 feet wide.	

From the above it will be seen that Beaver Dam is improving her streets mainly through the construction of limestone macadam pavements. The subsoil in this city is largely clay and for this reason a somewhat thicker foundation course is required than where the subsoil is sand and gravel.

Beaver Dam is located not far from an abundant supply of granitic rocks which ought at least to be used for the wearing surface. From the standpoint of maintenance limestone is an expensive material for macadam. In reality it is suitable only for the lower courses.

In the width of the pavement constructed, the city has adopted the correct principle. On business streets, the pavement is 50 feet wide, while on residence streets it is 18 feet. Eighteen feet may appear somewhat narrow for some residence streets, but a city is unwarranted in constructing a pavement which is unnecessarily wide, both on account of the greater cost of construction and the greater cost of maintenance.

Main street, formerly known as Front street, was macadamized in 1892. This street is 46 feet wide between the gutters and the macadam was one foot thick. Seven hundred and fifty lineal feet of the street were macadamized and it is stated that up to the present time the pavement has needed no repairs except in small spots where the street has settled. An examination of this pavement would probably show that it is at least partly worn through.

For the above inforamtion I am indebted to Mr. L. D. Livermore.

MAYVILLE.

(Pop., 1,815.)

The subsoil in this region is largely clay, although in some localities it consists of sand and gravel. Gravel is very abundant in this region and the streets of this city have been improved altogether by spreading gravel over the surface. Park, Main, German, Furnace, Breckenridge, Buchanan, Dayton, William, Bridge, Allen, Horicon, Naber, Cottage, Taylor and Turner streets have all been graveled during the last few years and are reported to be in good condition. The gutters are

mostly made out of small boulders. Very little curbing is used except where cement sidewalks are being constructed.

WAUPUN.

(Pop., 3,185.)

This city has only half a mile of improved streets. Main street was paved with broken limestone between 1896 and 1899. This pavement is reported to be in good condition, although during wet weather it is muddy and requires cleaning, which costs about $100 a year. The stone used on this street was obtained from the quarry of the Randall Stone Company.

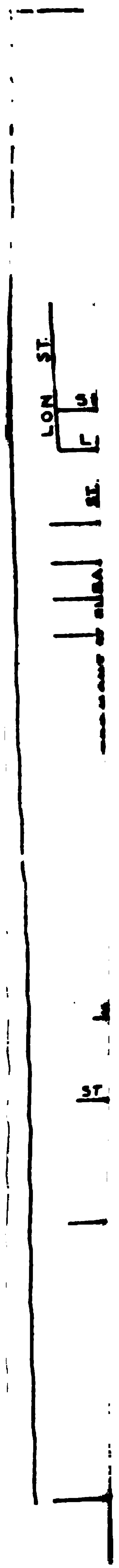
There is an abundance of limestone in this vicinity which is well suited for the foundation to macadam pavements. The stone, however, is too soft for surfacing and granite or trap rock should be shipped in for this purpose. The quarries at Berlin and Green Lake are not far from Waupun and from either place excellent stone can be obtained for this purpose.

It is understood that at the present time the city has no funds that can be devoted to street improvements. Until funds are provided the paving of the streets must wait.

WATERTOWN.

(Pop., 8,437.)

Main street from the bridge to College avenue and West Main street from the bridge to Montgomery street, a total length of 3,567 feet, were the first streets paved in Watertown. In 1899 these streets were paved with Galesburg brick, which were laid on a six inch concrete foundation. The total area paved amounted to 18,417 square yards. The street is from 36 to 50 feet wide between curbs and the cost of paving was $1.29½ per square yard, not including excavating, filling or setting curb, gutters, etc. The curbing cost 44 cents per lineal foot in place and the cost of excavating was 18 cents per cubic yard. The contract called for 6,575 lineal feet of curbing, 1,675 feet of protection curb, 66 lineal feet of cast iron gutters, 66 lineal feet of cast iron bridges, 614 lineal feet of wide gutter bridges and 7,285 cubic yards of excavation.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The specifications under which this pavement was constructed were written by G. H. Stanchfield, city engineer, and, except in a few particulars, were well gotten up. There are several points in these specifications with which I am not altogether in accord. It is thought that the pavement would have been equally as satisfactory if a well constructed macadam foundation had been used in place of concrete; it is doubtful if the repressed paving brick are preferable to those with the square corners and edges; and the joints should have been filled with portland cement grouting in preference to clean, dry sand.

It is expected to macadamize the residence streets, using mainly local limestone. The subsoil conditions in this city are favorable to this kind of pavement, and if granite or trap rock are used for top dressing the macadam ought to give good satisfaction.

DOOR COUNTY.

Door county is located in the northeast corner of the state, between Green Bay and Lake Michigan. The northern part of the county is rough and rugged, while the southern portion is more level and rolling. The soils are almost entirely clayey loams of the heavier varieties. In the southern part there are several areas of clayey loams derived from the red lacustrine clays, while along the lake shore occur occasional areas of sandy loam. Numerous small areas of humus soils, composed mainly of muck and peat, are scattered through the county.

Door county is in the glaciated region, and the deposits have contributed gravel and boulders suitable for road construction. With the exception of a small strip of land in the southwestern part bordering on Green Bay, the county is entirely underlain with Niagara limestone. Much of the limestone which outcrops in this part of the state is strong and durable and may be classed among the very best grades of limestone used for road metal.

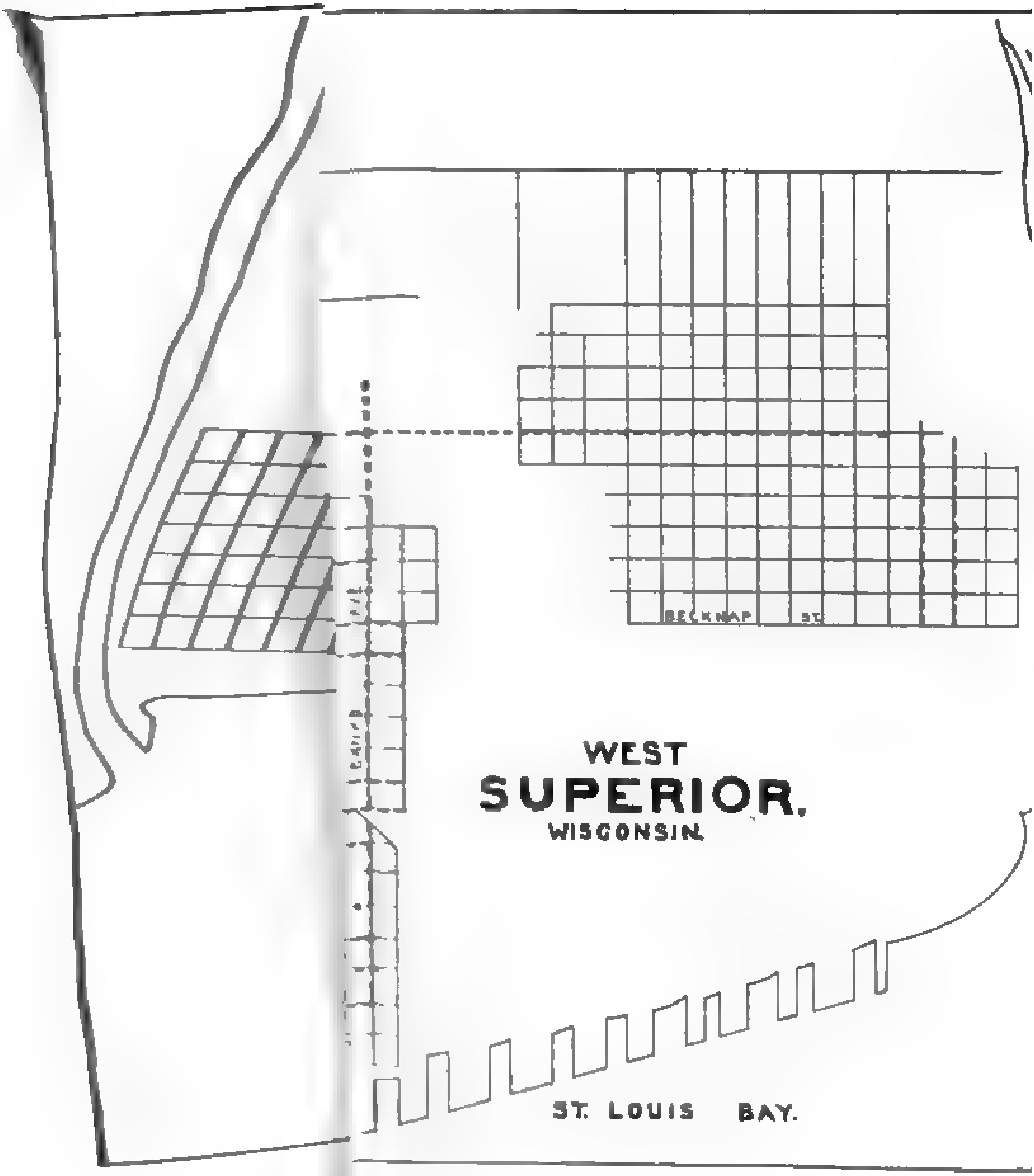
STURGEON BAY.

(Pop., 3,372.)

This city has about one mile of macadam pavements and two miles of graveled streets. The following is a list of the streets which have been improved.

Sturgeon Bay.

Name of street.	Date.	Materials Used in Construction.				Where material was obtained.	Average width of street between curbs.	Total cost of construction.
		Foundation.		*Surface.*				
		Kind.	Thickness.	Kind.	Thickness.			
Cedar..................	1895	Sand and clay ...	5 in.	Crushed limestone ..	5 in.	City stone quarry....	46 ft.	$560.03
Garland.	1898	Sand and clay...	5 in.	Crushed limestone ..	5 in.	City stone quarry....	46 ft.	....
Green Bay Road..	1895-99	Sand and clay...	4 in.	Gravel.....	4 in.	4th ward gravel pit..	46 ft.	22 59


BELKNAP ST.
WEST
SUPERIOR,
WISCONSIN.
ST. LOUIS BAY.

The crushed stone is obtained from the city limestone quarry. It is an excellent quality of limestone but is inferior to the granite and trap rock, which occurs as field stone scattered over the county. The cost of macadamizing the streets is very low and it ought to be possible for the city to soon improve all of the streets in this manner.

DOUGLAS COUNTY.

Douglas county is located in the northwest corner of the state. With the exception of that part bordering on Lake Superior, the surface is irregular and broken. The erosion along the lake shore and inland has modified the prevailing glacial topography. The soils in the northern part of the state are clayey loams derived from the red lacustrine clay. The soil in the southwestern and central portions is mainly a light clayey loam through which is scattered numerous areas of irregular humus soil composed mainly of muck and peat. The southeastern portion of the county has a sandy loam.

With the exception of a strip about six to twelve miles wide bordering on Lake Superior, the entire county is underlain with Keweenawan rocks consisting mainly of diabase, amygdaloid, melaphyre and other varieties of rock known as trap. These rocks outcrop in many places over the southern part of the county and constitute an inexhaustible supply of the very choicest stone for constructing macadam pavements. Crushing plants located either on the Chicago, St. Paul, Minneapolis & Omaha, the Duluth South Shore or Northern Pacific railroads ought to be able to supply Superior and Duluth with much of the stone which will be needed for macadam pavements.

WEST SUPERIOR.

(Pop. of Superior, 31,091.)

The only kind of pavement in West Superior, January 1st, 1900, was cedar block, of which there were thirty-six miles. The first of this pavement was laid in 1889 and the last in 1893. Records showing the cost of construction, cleaning and re-

pairing have not been properly preserved. Mr. A. T. Thomas, deceased, formerly city engineer, informed me that the cedar block lasted about eight years without needing repair. The streets today are very badly in need of repairs.

The curbing along the paved streets is sandstone and granite. It is in excellent condition and can be reset, when new pavements are laid, with very little expense.

The city is now contemplating the improvement of the streets in the residence districts with granite macadam. Up to the present time I have no knowledge that these pavements have been begun.

It is thought that the brick pavements should replace the cedar block on the business streets and that granite macadam should be laid in residence districts. A general plan of paving and maintaining the pavements should be adopted by the city and followed out through consecutive administrations.

DUNN COUNTY.

Dunn county is located in the west central part of the state. With the exception of a small area on either side of the Red Cedar and Chippewa rivers, this county has a moderately regular rolling surface. The western part of the county has clayey loams of the light and heavy varieties. The eastern two-thirds of the county is covered with a sandy loam which, along the main stream channels, is almost entirely sand.

The surface of the county is covered with drift deposits of the earlier glacial epochs. In some parts of the county the granitic and other igneous boulders associated with the drift might be crushed and used for constructing macadam pavements.

With the exception of the tops of a few of the hills in the southeastern part, the county is entirely underlain with sandstone of the Potsdam formation. Certain of the harder beds of the limestone in the western part of the county might be crushed and used for road metal. In the remainder of the county, stone must be obtained from the drift or be shipped in from other localities. Chippewa Falls is one of the nearest

sources of supply for granitic rocks. Some of the shaley beds of the Potsdam sandstone might be used to make temporary improvements.

MENONOMIE.

(Pop., 5,655.)

There are no macadam or other pavements within the limits of this city. In 1899 Senator J. H. Stout secured the services of Special Agent E. G. Harrison to construct a section of model broken stone road half a mile long and twelve feet wide, beginning at the northwest corner of the Dunn county fair grounds and extending toward the Dunn county asylum. This road was built in two sections, each a quarter of a mile long. The west one-fourth of a mile was prepared with a gravel foundation four inches thick while the east one-fourth of a mile had a foundation of crushed rock of the same thickness. The surface of the roadway consisted of fine crushed granite and trap rock, all of which was shipped from Chippewa Falls. Owing to the scarcity of screenings, the voids in the foundation were filled with sand. Each course was thoroughly wetted and compacted with a horse power roller.

This piece of road is described and illustrated in Bulletin 79 of the Agricultural Experiment Station of the University of Wisconsin.

EAU CLAIRE COUNTY.

Eau Claire county is located in the west central part of the state. With the exception of the valleys of the Eau Claire and Chippewa rivers with their tributaries, Eau Claire county has a comparatively level surface. Except in the extreme northeast corner, the soils are either sand or sandy loams. The county contains very little clayey soil except in the northeast corner. The sandy soils occur mainly along the flood plains of the Chippewa and Eau Claire rivers and their tributaries.

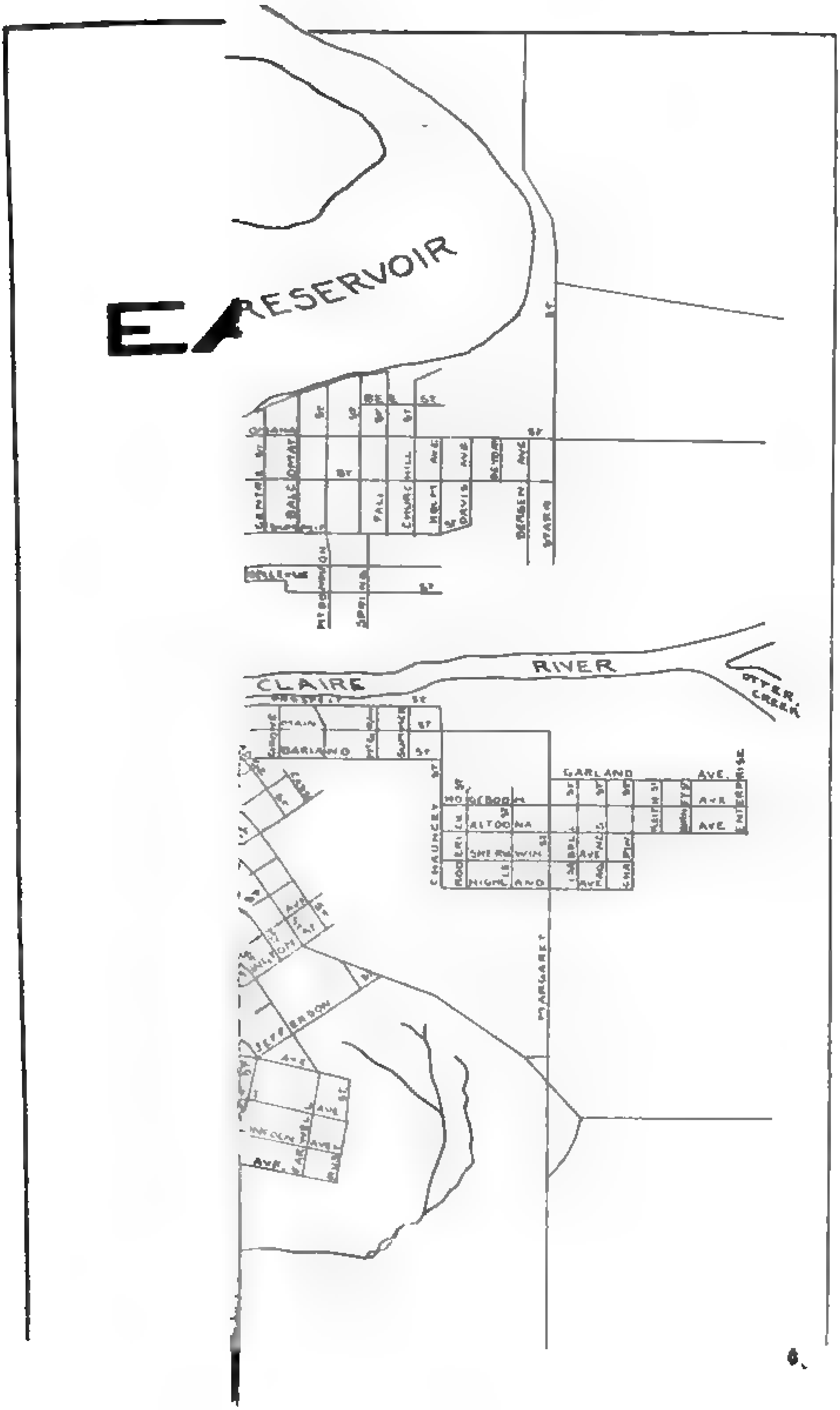
The county is within the region covered by the ice of the earlier glacial epochs. As in the case of Clark county, the mantle of till is, in most parts, relatively thin.

An area of about 125 square miles of the northeastern part of the county is underlain with pre-Cambrian rocks of the granitic type. The remainder of the county is underlain with sandstone of the Potsdam formation. As explained in connection with other counties similarly situated the only sources of materials for road construction are the occasional shaley and quartzitic layers of the Potsdam formation; the gravel which occurs along some of the stream channels; and the granitic and gneissoid rocks in the northeastern part of the county. The latter should constitute the most important source of supply. In some places along the Eau Claire river, the gneissic rocks are in a semi-disintegrated condition and it is believed that the ease with which they can be obtained will make them very valuable as a road metal.

EAU CLAIRE.

(Pop., 17,517.)

In company with most of the other cities located in the lumbering region, Eau Claire built her first pavement out of cedar blocks. This was in 1888. During that and the two succeeding years, the city constructed 3¾ miles of cedar block pavement at an expense of $109,297.95, which is at the rate of $1.16 per square yard. The following is a list of the street paved up to 1901 with the date of construction, cost, etc.


RESERVOIR
CLAIRE
RIVER
OTTER CREEK
GARLAND AVE.
ENTERPRISE
ALTOONA
SHERWIN
HIGHLAND
CHAUNCEY
MARGARET
JEFFERSON
SPRING
STARR
BERGEN
CHURCHILL
DAVIS
FALL
MAIN

Eau Claire.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction.		Where material was obtained.	Av. width of street between curbs.	Cost of construction per sq. yd. including curb	Kind of curbing.	Total cost of construction.
			Foundat'n	*Surface.*					
North street	From Madison to Wisconsin.	1889	Wood.....	Cedar block....	....	34 and 42 6t.	$1.04	Limestone and wood.	$1,040.58
Wisconsin	From North to N. Barstow.	1889	Wood.. .	Cedar block....	....	38 and 56 ft.	1.02	Limestone and wood.	8,037.41
Galloway.	From N. Dewey to N. Barstow.	1888	Wood.....	Cedar block....	....	53 ft.	1.49	Limestone.	5,015.00
N. Barstow	From Madison to Eau Claire.	1888	Wood.....	Cedar block....	....	42 ft.	1.51	Limestone.	7,961.50
N. Dewey.........	From Galloway to Eau Claire.	1888-89	Wood.....	Cedar block....	....	31 ft.	1.12	Limestone and wood.	2,072.73
[1] S. River.	From Eau Claire to Kelsey.	1889	Wood.....	Cedar block....	....	42 ft.	1.13	Limestone.......	3,649.31
S. Barstow........	From Eau Claire to Newton.	1888-89	Wood. ...	Cedar block....	....	42 ft.	1.32	Limestone.......	20,621.31
S. Barstow........	From Eau Claire River to Gray.	1899	Gravel....	Vitrified brick .	Galesburg..	42 ft.	1.35	Limestone	10,104.31
S Farewell...	From Eau Claire to Kelsey.	1889	Wood.....	Cedar block....	....	42 ft.	1.12	Limestone.	2,951.37
S. Dewey..........	From Eau Claire River to Eau Claire.	1889	Wood.....	Cedar block....	....	42 ft.	1.17	Limestone.	1,672.50
[2] Eau Claire.......	From S. Dewey to S. River.	1889	Wood.....	Cedar block....	....	42 ft.	1.61	Limestone.......	6,046.82
Gibson	From S. Farwell to S. River.	1889	Wood.....	Cedar block....	....	42 ft.	1.19	Limestone.	2,735.93
Kelsey	From Doty to Chippewa river.	1888-91	Wood. ..	Cedar block....	....	34 and 42 ft.	1.23	Limestone and wood.	7,231.00
Grand Ave.... .... (formerly Kelsey)	From Barstow to Chippewa river.	1899	Gravel....	Vitrified brick .	Galesburg .	42 ft.	1.39	Limestone.	2,644.69
Second Ave	From Bridge to Water.	1890	....	Cedar block.. .	....	30 and 40 ft.	.91	Wood	9,396.63
4th Ave...........	From Lake to Water.	1889	....	Cedar block....	....	38 ft.	.91	Wood	7,698.48
Seminary	From Bridge to Lake.	1889	....	Cedar block....	....	38 ft.	.92	Wood	2,225.68
Bridge	From Chippewa river to Seminary.	1889	....	Cedar block....	....	38 and 42 ft.	1.02	Limestone and wood.	5,780.08
Water.	From 2d Ave. to 5th Ave.	1890	....	Cedar block....	....	56 ft.	1.14	Limestone.	2,674.69

[1] Replaced in 1899 with macadam built out of crushed quartzite from Ableman, Wis.
[2] One block in 1899 with macadam built out of crushed quartzite from Ableman, Wis., between River and Barstow streets.

It will be noticed from an examination of the above table, that South River and Eau Claire streets were replaced in part by quartzite macadam in 1899 and that South Barstow and Grand avenue(formerly Kelsey street) have been repaved with Galesburg paving brick. The brick were laid on a sand and gravel foundation and the joints were filled with sand. Seven thousand four hundred eighty-two yards of brick were laid in 1899 at a cost of $1.35 per square yard.

The city of Eau Claire is working under a special charter in which there is a provision by which the aldermen have control of a certain part of the funds available for street improvements. Owing to this provision in the charter, the city engineer has very little control over the kind of pavement built or the method of construction. For example, the replacement of the cedar block pavement with macadam on South River street was done without the approval of the city engineer. It is not intended to infer that the city engineer would have altered the specifications, but I simply mention this to point out one of the avenues which is open to abuse in this city.

Every city should have a department of public works to which all matters pertaining to street improvements should be referred.

It is needless to say that the streets which have been paved with cedar block are in very poor condition. The streets which have been paved with brick have not been used sufficiently long to pass judgment on their durability. The method employed in constructing the pavement was not the most approved and the surface may not remain smooth as long as it ought under a different method of construction. The quartzite macadam with which some of the streets have been repaved will undoubtedly prove more satisfactory than the cedar blocks.

A great many of the streets in the city have been improved with river gravel which, in some cases, has been mixed with decomposed sand rock from the quarries. This quarry rock contains considerable clay in the shape of thin layers and when broken up it forms a mixture of clay and sandstone. It has been found that by mixing this clay with the river gravel a much better street

can be made than when the gravel is used alone. Whenever it is necessary to improve a street, temporarily, I believe that the plan of mixing river gravel with this so-called shale is the very best that can be adopted. Such an improvement will wear for several years with very little repair, giving a hard street during ordinary conditions of weather.

It costs about $500 a year to clean the 2,000 feet of brick pavement in the business section of the city. This relatively large cost is due to the mud and dirt which is brought onto the pavement by the teams from the adjoining streets. The relative cost of cleaning will undoubtedly decrease as the mileage of brick pavement increases.

AUGUSTA.

(Pop., 1,256.)

None of the streets in this village have been paved. The soil is sandy and each year a coating of clay is added to the surface. No curbing has been used and Mr. Johnson, the city clerk, says that the "surface water flows along the line of least resistance to the creek." The city expects to begin macadamizing the business streets very soon.

FLORENCE COUNTY.

Florence county is located in the northeastern part of the state on the Michigan boundary line. The surface of this county is rolling and more or less hilly. The western two-thirds of the county has a light clayey soil. The western part is mainly sand and sandy loam. Irregular areas of humus soils, composed mainly of muck and peat, are scattered through the county.

The county is entirely underlain with pre-Cambrian rocks of the granitic, gneissoid and trap varieties. There are numerous outcrops of these rocks in different parts of the county, furnishing an inexhaustible supply of excellent stone for macadam pavements.

As a result of the glaciers, deposits of gravel and boulder clay

occur in various portions of the county. The gravel and boulders are another important source of stone for road metal.

FOREST COUNTY.

Forest county is located in the northeastern part of the state on the Michigan boundary line. The surface of the county is rough and rolling in some parts, having been, as a rule, modified by the erosion and deposition of the glacial period.

The soil is very largely a clayey loam, except in the northwestern portion, where it changes into a sandy loam. Throughout the county there occur numerous areas of humus soils composed mainly of muck and peat.

Glacial deposits in the form of morainal drift are found mainly in the southern and eastern parts. The character of these deposits have never been examined and their value for road metal is unknown.

The entire county is underlain with pre-Cambrian rocks of the granitic and gneissoid varieties. These rocks are known to outcrop at numerous places and in time will provide an inexhaustible supply of road metal.

FOND DU LAC COUNTY.

Fond du Lac county is located in east central Wisconsin at the south end of Lake Winnebago. The surface of the county is rolling and hilly, especially in the southeastern portion where it is traversed by the kettle moraine of the last glacial epoch. The soil of this county is largely a clayey loam. Adjacent to the lake, the soil has been derived from the red lacustrine clays and is of a heavy variety. In the eastern part of the county there is a belt of heavy clayey loam. Small areas of prairie loams and humus soils are found in different parts of the county. In the southeast corner there is an area of calcareous sandy loam.

The surface of the county has been modified by the erosion and deposition accompanying the glacial period. Beyond the lacustrine clay area there are numerous deposits of drift made

up of boulder clay and gravel. Some of these contain material which is well adapted for road improvements.

The eastern part of the county is underlain with magnesian limestone. West of this occurs a thin belt of Hudson River shale; a wide area of Galena limestone; small areas of Trenton limestone; St. Peters sandstone; and, in the extreme western part of the county, Lower Magnesian limestone. There are abundant outcrops of limestone in this county and the quarries at Marblehead, Pebbles, Hamilton, Brandon and Ripon supply large quantities of stone for local consumption. As noted with reference to other quarries, the stone from some of the beds is far more suitable for street paving than that obtained from others. A careful detailed examination of the different beds, accompanied by laboratory tests of the stone would assist very greatly in the selection of the best stone for paving purposes.

BRANDON.

(Pop., 663.)

The subsoil in this region consists mainly of clay. At one time the streets of this village were covered with crushed rhyolite obtained from the quarries at Utley. Since that time the streets have been graveled each year. The combination of the broken stone foundation and gravel surface apparently makes a very good pavement. The surface water is removed by means of gutters and ditches. The village is located on a high point providing natural facilities for carrying off the water. The street gutters are built out of stone and the curbing is limestone obtained from quarries near the city. The crosswalks are constructed out of limestone flagging which is also obtained from the local quarries.

FOND DU LAC.

(Pop., 15,110.)

Fond du Lac has 6 miles of cedar block pavement, 7-12 of a mile of brick, 1 mile of limestone macadam and 10 miles of gravel. The following is a list of the streets paved.

Fond du Lac.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction. Foundation. Kind.	Foundation. Thickness.	Surface. Kind.	Surface. Thickness.	Where material was obtained	Average width of street between curbs.	Cost per lineal foot.	Total cost of construction.
Main			Hemlock plank.	2 in	Cedar block	6 in.		44 ft.	$5.00	
Division			do	do	do	do		30 ft.	do	
Sheboygan			do	do	do	do		do	do	
First			do	do	do	do		do	do	
Second			do	do	do	do		do	do	
Third			do	do	do	do		do	do	
Fourth			do	do	do	do		do	do	
Harney			do	do	do	do		do	do	
Merrill			do	do	do	do		do	do	
Johnson			do	do	do	do		do	do	
Forest		1897	Concrete	6 in.	Brick	4 in.		do	7.00	
E. First		1898	Macadam	8 in.	Limestone macadam.	6 in.	Marblehead	do	3 00	
W. Division	From W. of river to Brooke		Concrete	6 in.	Brick		Galesburg	do		$12,000 00
Linden			Crushed limesone	8 in.	Crushed limestone.	6 in.	Marlbehead	do	3.00	
Western Ave			Crushed limestone		do	6 in.	Marblehead	do	3.00	

The cedar block pavement has proven itself to be illy adapted to the conditions existing at this place. The brick and macadam pavements have not been in use sufficiently long to warrant any positive statements as to their suitability for the streets on which they have been constructed.

Many of the streets in this city are laid out through low marshy tracks of land which have been filled with shavings, pine slabs and other refuse from the saw mills. Anything has been used which would serve to temporarily improve the highway. Where the road has not been filled with slabs and saw dust, the subsoil is often a sticky red clay, which is a very undesirable material on which to lay any kind of a pavement. In this city the engineer has, perhaps, the most undesirable kind of subsoil on which to construct a permanent pavement. In order to insure a stable pavement it is necessary to remove the subsoil to a depth of from 12 to 15 inches and replace it with sand or gravel. In some instances it has been necessary to excavate to a depth of several feet and fill with coarse rubble stone in order to provide the necessary subsoil conditions.

The only street paving which has thus far been under the direct supervision of the city engineer is the one-fourth of a mile of brick pavement on West Division street between Brooks and the Fond du Lac river bridge. This pavement, which was laid in the summer of 1901, had a 6 inch concrete foundation, made out of Louisville cement and crushed limestone. The brick were laid on a cushion of sand and the joints were filled with sand. This pavement has a very high crown and deep inlets at the catch basins. The curbing was laid on a foundation of sand and gravel. The street was graded and the foundation and surface laid at a cost of $1.77 per square yard. The Berea sandstone curbing, which was used on this street, cost 51 cents per running foot.

The subsoil conditions in this locality are of such a nature that it would seem advisable to set the curbing on concrete, as well as to use concrete for the foundation to the pavement. It would certainly be wise to fill the joints with portland cement grouting.

Forest street, between the Fond du Lac river bridge and the Northwestern railway tracks, was paved with brick in 1897. This pavement was laid on a 6-inch concrete foundation, the joints were filled with sand, and the crown was made very much lower than that of the pavement on West Division street. For some reason or other this pavement shows frequent depressions on the surface in which water often accumulates. This pavement is subjected to the heaviest teaming of any in the city and shows very little deterioration in the shape of chipped or broken brick.

A great many of the streets of this city are being improved by the addition of unscreened broken limestone. This broken limestone is obtained from the Marblehead quarries at a cost of $3.00 per car. The stone chips are spread on the street to a depth of about 10 or 12 inches, well watered and rolled with a 14 ton roller. The streets are not well graded, but the addition of the stone makes a vast improvement over the clay, shavings, slabs, etc. These street improvements are under the immediate supervision of the street suprintendent, and are looked upon in the form of repairs rather than permanent constructions. I believe that later these broken stone surfaces will make excellent foundations, upon which to build macadam pavements having granite and trap rock for the wearing surface. By the addition of several inches of granite or trap rock surface, Fond du Lac might have very excellent pavements at a reasonable cost.

This city exercises no control over the construction of the sidewalks and allows the use of boards, brick or any other material. There is likewise no established system of street maintenance. Without some control over sidewalk construction and a permanent system of street maintenance, it is impossible to keep the highways in good condition. The new pavements are paid for by assessing one-third of the cost against the city and two-thirds against the property benefited.

On many of the streets sufficient attention has not been paid to the construction of gutters for the removal of the storm water. Flag stone gutters, about 3 feet broad, have been constructed along some of the streets. The flagstones, however,

have been laid without sufficient attention to the foundation, and have settled unevenly making a very rough surface.

Very little attention has been given to parking the residential streets. This city should inaugurate a system of street improvement and maintenance which will insure clean, quiet and beautiful thoroughfares.

RIPON.

(Pop., 3,818.)

Ripon has one street paved with brick and about fifteen miles of graveled streets, which cost about $200 per mile per year for maintenance. The following is a list of the streets which have been graveled and paved since 1892.

Ripon.

Name of street.	Date.	Materials Used in Construction.				Where material was obtained.	Aggregate width of street between curbs	Cost of construction per sq. yd. exclusive of curb, gutter and underground pipes.
		Foundation.		*Surface.*				
		Kind.	Thickness.	Kind.	Thickness.			
E. Fond du Lac		Gravel	7 in.	Gravel	6 in.	Ripon	54 ft.	$0 35 per sq. yd.
Hall		Clay	2 ft.	Gravel	6 in.	Ripon	54 ft.	0.35 per sq. yd.
Eureka		Clay	2 ft.	Gravel	6 in.	Ripon	54 ft.	0.35 per sq. yd.
Woodside	1896	Gravel	6 in.				4 rods.	
Hall	1892	Black earth		Gravel	6 to 8 in.	Ripon	4 rods.	
W. Fond du Lac	1893	Black earth		Gravel	6 to 8 in.	Ripon	4 rods.	
Watson	1897	Black earth		Gravel	6 to 8 in	Ripon	4 rods.	
Blackburn	1899			Gravel	6 to 8 in	Ripon	4 rods.	
E. Fond du Lac	1886	Black earth		Gravel	12 in.	Ripon	4 rods.	
Eureka	1894	Black earth		Gravel	8 in.	Ripon	4 rods.	
Case	1894	Stone		Gravel	12 in	Ripon	8 rods.	
Main	1901	Concrete	6 in	Brick	4 in.	Canton, Ohio		

with hammers on the street and laid to a depth of from one to one and a half feet. The surface of the street was covered with a thin layer of gravel. Gutters, two and a half feet wide, were built out of common rubble stone, set on edge. The subsoil is clay and loam.

Most of the streets have been improved by the addition of gravel taken from Blakes creek. The crushed stone is obtained from a quarry near the city.

CASSVILLE.

(Pop., 979.)

The streets of this village are graveled, the work being extended each year as far as the funds will permit. One of the streets has been covered with broken stone from Bluff street to the river. The streets are reported to be in very good condition.

FENNIMORE.

(Pop., 1,035.)

Between 1893 and '95 the village of Fennimore paved Lincoln avenue for a distance of 1,655 feet with limestone blocks 8 inches in thickness, laid on a sand foundation of 10 inches. The street is 50 feet wide and the cost of construction was about $7,000. Up to 1901 the pavement had required no repair, and the cost of cleaning amounts to only $10.00 a year. The limestone was obtained from quarries near the city.

This pavement was comparatively cheap, costing only about 78c. per square yard. However, the surface of the pavement is rough and therefore noisy. In a village of this size teams are seldom driven over the street after 11 o'clock and the quiet of the place is seldom unduly disturbed. No one cares to use the pavement for pleasure driving and it is much cleaner than the dirt road.

The pavement is not very elegant, but it is certainly serviceable and there is perhaps no city or village in the state that has constructed a pavement which will eventually prove as cheap and serviceable as the limestone block which has been constructed in this village.

This county is almost entirely underlain with granitic and metamorphic rocks, belonging to the pre-Cambrian formations. In the western part the rocks are mainly quartzite, while in the central and eastern portions they are granitic and gneissoid in nature. In the southwestern part of the county is a small area of Potsdam sandstone. This county is well supplied with suitable stone for road metal. The numerous outcrops occurring in various parts of the county and the field stone strewn over the surface, constitute an inexhaustible supply of stone for road metal.

GRANT COUNTY.

Grant county is located in the southwestern corner of the state. The Wisconsin, Grant and Platte rivers, with their tributaries, have trenched the land in such a manner as to make some portions of the county very hilly. The bluffs along the Mississippi and Wisconsin rivers are steep, and the roads traversing these parts of the county have very sharp grades. The soil along the Mississippi and Wisconsin rivers is mainly a sandy loam. The remainder of the county is covered with prairie loams and lighter varieties of clayey loams.

This county is located in the driftless area, on account of which the topography is of the simply erosion type.

The ridge and prairie land areas are all underlain with Galena limestone. Along the river channels, however, not only the Galena limsetone, but also the Trenton, St. Peters and Lower Magnesian formations are exposed. The harder beds of the Galena and Trenton limestones provide the most desirable road metal occurring within this county. The flint gravel which occurs along some of the stream channels, if mixed with crushed limestone, ought to increase the durability of the broken stone pavement. A combination of gravel and limestone should be used wherever possible.

BLOOMINGTON.

(Pop., 611.)

Two blocks of Congress street, north of Canal, were macadamized in 1899. The stone used for this purpose was broken

with hammers on the street and laid to a depth of from one to one and a half feet. The surface of the street was covered with a thin layer of gravel. Gutters, two and a half feet wide, were built out of common rubble stone, set on edge. The subsoil is clay and loam.

Most of the streets have been improved by the addition of gravel taken from Blakes creek. The crushed stone is obtained from a quarry near the city.

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The pavement is not very elegant, but it is certainly serviceable and there is perhaps no city or village in the state that has constructed a pavement which will eventually prove as cheap and serviceable as the limestone block which has been constructed in this village.

PLATTEVILLE.

(Pop., 3,340.)

Platteville has about four miles of limestone macadam and three miles of graveled streets. The first macadam pavement was constructed in 1890, additions being made yearly since that time. The principal streets are cleaned in the spring by raking and shoveling the mud and dirt into piles and carting it off with teams. All the main roads leading into the city are macadamized as far as the city limits. The foundation to the macadam pavement consists of twelve inches of crushed limestone or creek gravel. The surface consists of three inches of fine crushed limestone or creek gravel. The limestone is obtained from a quarry owned by the city and the gravel is obtained in abundance from the creek bottoms near the city limits.

Mr. D. E. Gardner, to whom I am indebted for this information, says that the crushed limestone makes an excellent pavement, but disintegrates and wears away in time. He says, however, that with a little repair the pavements will be good for many years.

The creek gravel costs about half as much as the crushed limestone and Mr. Gardner believes that it really makes as good a road. The crushed limestone costs $1.25, while the gravel costs 57c. per cubic yard. The city plans to extend the macadam about one mile each year.

GREEN COUNTY.

Green county is located in the south central part of the state on the Illinois-Wisconsin boundary line. It is situated partly in the glaciated and partly in the driftless area. The surface in the western part, which is in the driftless area, is rough and hilly, while that of the eastern glaciated section is more of the rolling, regular type. About two-thirds of the county is covered with a thin mantle of drift, as a result of the earlier glacial epochs. The glacial deposits consist of boulder clay, sand and gravel, which in some places can be used advantageously as a

road metal. The gravel is mainly limestone and usually well rounded. Alone, it is not a desirable road material, but when used with crushed stone of the granitic or trap varieties, a good pavement can be made.

The soils in the eastern part of the county are largely sandy loams, while those in the western part consist of the lighter varieties of clayey and prairie loams. The eastern part of the county is mainly underlain with St. Peters sandstone, to which is largely due the sandy loams of this area. The western two-thirds of the county is underlain very largely with Galena limestone, although the Trenton limestone and St. Peters sandstone are exposed very prominently along the stream channels.

The gravel and boulders of the glacial drift and the harder layers of Galena limestone will, undoubtedly, for many years, constitute the most important sources of road metal.

ALBANY.

(Pop., 797.)

The streets of Albany have been improved entirely by the addition of gravel. In East Albany there is a hill composed of a mixture of gravel and clay which, when spread on the road, packs into a hard, smooth mass resembling cement. Water, Main, Mechanic and Mill streets have been covered with this gravel. Several miles of very sandy roads north and east of Albany have also been improved with this gravel.

Mr. E. E. Atherton, to whom I am indebted for this information, says that roads which are treated with this gravel need little, if any, attention for years and that they are good all seasons of the year.

The subsoil in this region is mainly sand. Gutters and curbing are mainly built out of stone, although cement is being used to some extent. The village is built on rolling land and tho natural drainage is consequently very good.

MONROE.

(Pop., 3,927.)

The streets around the court house were improved a number of years ago with broken limestone which was spread over

the surface according to no definite plan. The street leading to the Chicago, Milwaukee and St. Paul depot has also been improved, in part, with limestone macadam.

The average limestone, which occurs in this vicinity, is loose-textured and too soft to make a durable pavement. This limestone will serve very well for the foundation course to a macadam pavement, but the surface or top dressing should be of granite or trap rock. Unless some such plan as this is adopted the macadamized streets will be muddy when wet and dusty when dry. The street around the court house should be paved with vitrified brick.

GREEN LAKE COUNTY.

Green Lake county is located in the east central part of the state, a little southwest of Lake Winnebago. The surface of the county is somewhat broken and contains isolated hills or knobs of pre-Cambrian rocks which rise above the surrounding country.

The soils in the southeastern half of the county are mainly prairie and clayey loams; those in the northwestern half are sandy loams. Several irregular areas of humus soils, composed mainly of muck and peat, occur in the western part. The surface is largely covered with glacial drift which varies greatly in composition and thickness. Gravel and boulders occur in different parts of the county and when properly selected and used are valuable as materials for road construction.

The southeastern portion of the county is underlain mainly with limestone of the Galena, Trenton and Lower Magnesian formations and the northwestern portion with sandstone of the Potsdam formation. In the southwestern, northwestern, northeastern and southeastern parts of the county occur small isolated hills of granite and porphyry belonging to the pre-Cambrian formations. The principal outcrops occur at Berlin, Utley and Marquette. The stone at these different localities constitute an inexhaustible supply of excellent road metal. This county, combined with Marquette, Waushara and Sauk,

ought to very largely supply the southwestern part of the state with the necessary road metal for the construction of macadam pavements.

BERLIN.

(Pop., 4,489.)

One of the most important industries in this city is the manufacture of crushed stone, paving blocks, crosswalks, etc., by the Illinois and Wisconsin Stone Company. The rhyolite, which is quarried here, is one of the very best stones which can be obtained for the manufacture of paving blocks, cross walks, curbing and macadam. Paving blocks and crushed stone are shipped from this quarry to all parts of the Upper Mississippi valley region.

In spite of the accessibility of the best of materials, it is interesting to observe that this city has not yet built a block of macadam pavement. The business street has been improved by grading and the addition of uncertain quantities of broken stone, but on none of the streets has a properly constructed macadam pavement been built.

PRINCETON.

(Pop., 1,202.)

Part of the streets of this villages have been graveled, but none of them have been improved with a permanent pavement of any kind. The subsoil in this vicinity is sand or clay. The gutters are usually built out of stone and the sidewalks out of pine lumber.

IOWA COUNTY.

Iowa county is located in the southwestern part of the state and is wholly within the driftless area. The surface in the northern, eastern and southwestern parts is rough and hilly. The remainder of the county consists of ridge land which is gently rolling. The soils of the ridge land are mainly prairie loams; those of the broken hilly sections are classed among the lighter varieties of clayey loams.

The ridge areas are underlain with Galena limestone. The bluffs along the river and stream channels expose not only the Galena limestone, but also the rocks of the Trenton and St. Peters formations. When used with the flint gravels which occur in places along the streams the Galena limestone ought to constitute the best local material available for road metal.

DODGEVILLE.

(Pop., 1,865.)

This city began the construction of broken stone pavements in 1860, and at the present time has a total of 1½ miles. No record has been kept of the methods or cost of constructing the pavements.

The estimated yearly cost of repairs is at present about $25 per mile. The cost of cleaning is about $125 per mile. Iowa, Diagonal, Main, North Main and Division streets have been macadamized with a thickness of from 6 to 8 inches of limestone. The entire width between curbs, 60 feet, has been paved. The city owns a rock crusher.

These are not ideal macadam pavements. The limestone used is of the softer type and the dust and mud which accumulate are sources of considerable annoyance. This city, however, is out of the granite and trap rock area and the cost of shipping in this stone for street surfacing almost prohibits its use.

MINERAL POINT.

(Pop., 2,991.)

For a number of years this city has been improving her streets by macadamizing with broken limestone. In 1899 Chestnut, Commerce and Fountain streets were partly improved in this manner, making a total of half a mile of pavement. The macadam consists of a foundation of coarsely broken limestone, to which is added twelve inches of finer crushed limestone. The stone from a very hard layer of the Trenton formation, known as the "glass" rock, is used for street paving. The limestone from this bed is hard and close textured and is better suited for macadam than the stone from any of the other beds.

The streets are repaired each year and are in fairly good condition.

The cleanliness and durability of the macadam might be increased if granite, trap rock, or quartzite were used for top dressing. There is a question, however, as to whether the traffic is heavy enough to warrant the additional expense which the use of this stone would incur. By exercising ordinary care in selecting the limestone, a very good pavement can be constructed.

It is interesting to note that in the early days, before zinc ores were mined in this region, the yellow and brown "dry bone" (smithsonite), which is now smelted for zinc, was used for improving the street. When the value of the "dry bone" became known the pavement was dug up and sold to the smelters as zinc ore.

MONTFORT.

(Pop., 627.)

One block on Fountain street and one on Main street were macadamized in 1896. Limestone from the immediate viciniy was used for this work. The macadam was built the full width of the street and stone was used for the curb and gutters. The subsoil is black loam.

IRON COUNTY.

Iron county is located in the northern part of the state on the Wisconsin–Michigan boundary line. The surface of this county is very broken and hilly on account of the Penokee iron range which passes through the northern part and the accumulations of glacial drift which are found in the southeastern portion. Besides this, the county is traversed by several short and rapid streams in the northwestern part and is dotted with small lakes in the southeastern portion. The soils in the northern part of the county are mainly heavy clayey loams, while those in the southeastern section are light clayey and sandy loams.

Some sections of the county are covered with heavy accumulations of sand and gravel. The quantity and character of the

gravels are not known. A careful examination would probably show them to be a valuable source of supply for road metal.

Iron county is almost entirely underlain with pre-Cambrian rocks. In the northern portion the rocks are mainly diorites, diabases and melaphyres, known as trap, whole those farther south are of a granitic and gneissoid character. This county is supplied with an abundance of the best kind of rock for road metal.

HURLEY.

(Pop., 1,850.)

No attempt has yet been made to systematically pave any of the streets of the iron range cities in Wisconsin. The material used on the streets of Hurley comes from the dump piles near the mines. This stone is a mixture of ferruginous slate and greenstone. It binds well, and when properly crowned makes an excellent road. Many of the roads connecting the different towns on the range have been improved by surfacing with this material, and are in an excellent condition. The best kind of macadam pavements could be constructed in all of the northern towns if the ferruginous slate, which comes from the mines, were mixed with twenty-five or thirty per cent of clean crushed trap rock.

The high percentage of hematite in the slate gives to the pavements a deep reddish brown color. The fine dust which collects on the streets during dry weather is carried away by the winds, and lodging on fences, sidewalks, wooden buildings, etc., imparts to everything a reddish brown color.

JACKSON COUNTY.

Jackson county is located in the west central part of the state. With the exception of occasional ridges and isolated bluffs, the surface away from the Black river is comparatively level. The soils are almost entirely sandy loams and sand. Humus soils, composed mostly of muck and peat, occur in scattered areas through the county, mainly in the southern portion.

The northeastern part of the county has been covered with

overwash from the glaciers, but otherwise the surface has been in no way modified by this agent.

With the exception of a narrow strip of pre-Cambrian rocks north of Black River Falls and a few isolated hills of granitic rocks east of the river, this county is entirely underlain with Potsdam sandstone. In numerous places throughout the county there are shaly beds of sandstone in the Potsdam formation, which if properly used, might constitute a valuable source of material for making temporary improvements to the country roads. Outside of this shaly sandstone the supply of road metal must come entirely from the granitic and gneissoid rocks along the Black river. These rocks constitute an inexhaustible supply of stone suitable for road metal. The semi-decomposed gneiss, which occurs along the Black river and its tributaries, can be used to great advantage on the country roads. It is easily obtained and contains sufficient clay to greatly improve the extremely sandy roads of this region.

BLACK RIVER FALLS.

(Pop., 1,938.)

Water street was the only thoroughfare in Black River Falls which was paved up to January, 1901. One block of this street was paved in 1897, with a thickness of 14 inches of granite macadam. This street is 65 feet wide between curbs and it cost $1,500 to improve one block.

During 1900 a portion of 2nd street was improved with clay and gravel. The bottom course consisted of 2 inches of granite and the top course of from 4 to 5 inches of river gravel cemented with clay. Second street has also been improved for a width of 60 feet, at a cost of about $50 per block. This improvement was paid for by the property owners and the cost is not accurately known.

The only other street that has been improved is Main street, running from the river west for two blocks. This has been covered with gravel, which is a great improvement over the heavy sand of which the subsoil in this city is composed.

An abundance of granite occurs in the river bed within the

city limits. The rock which has been used on the streets has been obtained at this place and was broken in a crusher owned by the county. The city owns neither a street roller nor a crushing plant. With the aid of a crusher to prepare the stone and a roller to compact the courses, this city ought to have excellent paved streets. This place might even become a center of supply for road materials for a large part of the surrounding territory.

MERRILLAN.

(Pop., 739.)

The streets in this village and the county roads leading into it have been improved with the so called shale which is quarried from the lower beds of the Potsdam formation. The sandstone at this place occurs in thin, hard layers, interlaminated with very plastic, green-colored clay. These layers are taken as they come from the quarry and spread over the middle portion of the street. The traffic soon breaks down the harder fragments and reduces the irregularities, making a smooth road.

This shale is very similar to that which occurs at Eau Claire, except that it contains more clay. It is an excellent material for temporarily improving country or village roads, and when well graded and rolled is as serviceable as many of the limestone macadam pavements.

JEFFERSON COUNTY.

Jefferson county is located in the southeastern part of the state. The topography is of the irregular rolling type characteristic of glacial deposits. The soils are mainly light and medium varieties of clayey loams. Irregular areas of humus soils, composed mainly of muck and peat, are found in various parts of the county.

The glacial drift varies in thickness, reaching several hundred feet in some parts of the morainal area. Hills and ridges of limestone gravel are abundant throughout the county, furnishing an inexhaustible supply of material for temporary road construction. This gravel, however, should not be entirely re-

lied upon for road construction. The limestone, of which it is composed, is usually too soft to wear well, and the smooth character of the pebbles causes it to pack with difficulty. It should be used in connection with crushed granite or trap rock boulders which are scattered abundantly through the drift in some sections of the county. In the northwest corner of the county occur a number of outcrops of quartzite belonging to the pre-Cambrian formations. This quartzite, known locally as the Waterloo quartzite, can be used to advantage as a road metal by mixing it with crushed limestone from one of the other formations.

This county is largely underlain with Trenton and Galena limestone. In the western part the St. Peters sandstone outcrops over a considerable area, while the Lower Magnesian limestone outcrops in a small area in the northeast corner.

The glacial boulders of granitic and trap rock strewn over the surface and the quartzite, when mixed with Trenton or Galena limestone, should make excellent macadam pavements.

FT. ATKINSON.

(Pop., 3,043.)

Ft. Atkinson has until lately given very little attention to the improvement of her highways. Several miles of streets have been improved by surfacing with gravel. The graveled streets are a vast improvement over the natural soil, which is apt to be muddy in wet weather. The nature of the subsoil depends upon the position of the land. It may be clay, black loam or sand and gravel.

Sometime during the last 10 years,—the date is unknown,—Main street and Whitewater avenue were covered with a thickness of 6 inches of broken limestone, obtained from a local quarry. This street is 66 feet wide and it is reported to be in very satisfactory condition at the present time. The cost of this improvement could not be ascertained. In 1900, three blocks on South Main street and four blocks on Sherman avenue were macadamized with broken limestone from a local quarry. The macadam was made twelve inches thick, quarry chips and cobble stones being used for the foundation and the finer grades of

broken stone for the surface. Seven blocks of this macadam cost the city $2,300.

In the vicinity of Ft. Atkinson it ought to be possible to obtain an abundance of granite and trap rock boulders which could be crushed to provide a durable wearing surface. The additional expense of purchasing and crushing this stone would be fully compensated for by its greater wearing capacity. A city of this size should construct macadam pavements having granite for the wearing surface. The streets should also be provided with broad gutters built out of flag stone, vitrified brick, concrete or cobble stone.

JEFFERSON.

(Pop., 2,584.)

The only street improvements, which have been made in this city, have been by the addition of gravel. The streets are graded and graveled throughout most of the city, but there are no data available by which one can ascertain either the quantity or cost of the work. From two to three miles of the streets are improved or repaired each year.

All of the street work, including the building of walks and graveling of streets, is paid for by the city out of the general fund. This method of paying for street improvements seems to have retarded the city from making necessary street improvements.

JUNEAU COUNTY.

Juneau county is located in the west central part of the state and is comparatively level, except in the southern part. The county is located in the driftless area and the topography is altogether of the erosion type. The county contains extensive areas of marsh land, especially in the northeastern corner where the soils are of a humus character, consisting mainly of muck and peat. The soils in the eastern part along the Wisconsin river are mainly sand. Those in the southern and southwestern portions are mainly sandy loams. Small areas of clayey

loams occur in the southwestern and other sections of the county.

Near the central part of the county at Necedah there occur several hills composed entirely of quartzite belonging to one of the pre-Cambrian formations. With this exception the rocks in this county consist almost entirely of Potsdam sandstone. Several of the small ridges in the southwestern part are capped with unimportant thicknesses of Lower Magnesian limestone.

Many of the roads in this county pass over long stretches of sand in which stone suitable for road metal does not occur. Shaly sandstone layers, suitable for making temporary improvements to the highways, undoubtedly occur at some places in the Potsdam formation. The rocks, however, have not been examined in sufficient detail to know where these beds occur. The quartzite at Necedah ought to constitute a valuable source of road metal. There is an unlimited supply of quartzite at this place which, if mixed with crushed limestone or fine limestone gravel, ought to make excellent macadam pavements.

WONEWOC.

(Pop., 811.)

In 1897 this city began to construct macadam pavements, building about one block each season. Up to January 1st, 1900, the south half of Main street had been paved with quartzite macadam.

In the laying of the pavement the street is first brought to the proper grade by filling and excavating where necessary. Next, the curb stones, which are four inches thick, two to three feet long and twenty inches deep, are set. They are backed up to within eight inches of the top with clay.

After the curbing has been set, a layer of coarse, crushed stone is spread over the road to a thickness of three inches. One inch of clay is spread on top of this and the whole is wet with a sprinkler and rolled with a four ton roller. After this course has been thoroughly rolled, a second layer of crushed stone is laid to a thickness of three inches. One inch of clay is again added and the sprinkling and rolling repeated as in the case

of the first layer. On top of this second course is added a thickness of three inches of fine screenings and one inch of clay, all of which is rolled to conform to the established grade of the finished street.

The street on which this pavement has been constructed is 56 feet wide. The pavement cost about 65c. per square yard. The use of hard vitreous quartzite and clay, in the manner outlined above, is worthy of careful attention. Quartzite is one of the best materials which can be obtained for macadam pavement, provided one succeeds in bonding the surface. Care should be exercised not to use more clay than is necessary because, thereby, one is liable to destroy to some extent the stability of the pavement. The Wonewoc pavement is in excellent condition today. No difficulties were experienced in laying the pavement and thus far there has been no need for repairs.

KENOSHA COUNTY.

Kenosha county is located in the southeast corner of the state. The surface is comparatively level, except in the western part, where the topography is typical for a terminal morainal area. The soils are mainly light and heavy clay loams. Irregular areas of humus soils, composed of muck and peat, occur in various parts of the county. There is a narrow strip of land bordering on the lake on which the soil is sandy.

The county is entirely underlain with Niagara limestone. The principal sources of material for road metal are the granitic and trap boulders, which are strewn abundantly over the surface in the western part of the county, and the Niagara limestone. The latter can be used to best advantage with crushed granite or trap rock.

KENOSHA.

(Pop., 11,606.)

Up to January 1st, 1901, Kenosha had $3\frac{1}{4}$ miles of brick pavement and $1\frac{1}{2}$ miles of limestone macadam. The first brick pavement was constructed in 1893 and the last in 1901.

The yearly cost of cleaning these pavements is about $100 per mile, and the city engineer says that when not torn up to lay or repair pipes there is no better pavement. The first limestone macadam pavement was constructed in 1897 and the last in 1900. The yearly cost of cleaning this pavement is about $150 per mile. The city engineer has observed that this pavement wears rapidly under heavy traffic and is often very dusty in summer.

The following is a list of the streets paved up to January 1st, 1901.

Kenosha.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction. — Foundation. Kind.	Foundation. Thickness.	Surface. Kind.	Surface. Thickness.	Where material was obtained.	Average width of street between curbs.	Cost of construction per sq. yd., exclusive of curb, gutter and underground pipes.
Main...... ...	From Harbor to South.... .	1893	Limestone macadam.	6 in.	Brick	Single......	Galesburg, Ill.	43 ft.	$1.66
Market........	From Main to W. Main.	1896	Limestone macadam.	6 in.	Brick	Single......	Galesburg, Ill.	30 and 34 ft.	1.25½
Park Ave.	From South to City Limits...	1896	Limestone macadam.	6 in.	Brick	Single......	Galesburg, Ill.	33 ft.	1.25½
Prairie Ave ..	From Park Ave. to City Limits	1897	Limestone macadam.	6 in.	Brick......	Single......	Galesburg, Ill.	38 ft.	1.14
Grand Ave....	From N. Main to City Limits.	1899	Limestone macadam.	8 in.	Brick..	Single......	Galesburg, Ill.	34, 32, 30 ft.	1.33
Wisconsin.....	From Main to Chicago........	1899	Limestone macadam.	8 in.	Brick..	Single......	Galesburg, Ill.	42 ft.	1.26
Park street ...	From Main to Chicago	1899	Limestone macadam.	8 in.	Brick..	Single......	Galesburg, Ill.	42 ft.	1.26
S. Main........	From South to Town Line....	1899	Limestone macadam.	8 in.	Brick......	Single	Galesburg, Ill.	42 ft.	1.38
E. Market. ...	From Main to Exchange......	1899	Limestone macadam.	8 in.	Brick......	Single	Galesburg, Ill.	42 ft.	1.38
Durkee Ave...	From Deming to City Limits.	1897	Limestone macadam.	10 in.	Limestone .	Screenings .	Racine.	34 ft.	.56
Deming St....	From Durkee to Park Ave....	1897	Limestone macadam.	10 in.	Limestone .	Screenings .	Racine.	30 ft.	.63
S. Chicago St.	From Prairie Ave. to Deming.	1899	Limestone macadam.	12 in	Limestone .	Screenings .	Racine	34 ft.	.69
Park Row.....	From Durkee to Park Ave....	1897	Limestone macadam.	10 in.	Limestone .	Screenings .	Racine	30 ft.	....
S. Chicago....	From Deming to Julius	1900	Limestone macadam.	12 in.	Limestone .	Screenings .	Racine	34 ft.	.65
Julius.........	From Chicago to Ashland.....	1900	Limestone macadam.	12 in.	Limestone .	Screenings .	Racine	30 ft.	.65
Pearl..........	From Main to Lake....... ...	1899	Limestone macadam.	8 in.	Single course.	....	Galesburg, Ill.	42 and 30 ft.	1.27
Lake	From Pearl to Harbor..... ...	1899	Limestone macadam.	8 in.	Brick	....	Galesburg, Ill.	30 ft.	1.27

From the above table it will be observed that all of the brick pavements have been laid on a foundation of limestone macadam, which I believe will prove as satisfactory as concrete where the traffic is no heavier than it is in this city. If this city extends the macadam pavements to other streets, granite or trap rock should be used for surfacing. In addition to this a system of maintenance should be established by which these pavements can be kept up.

Brick gutters are used in connection with the macadam pavements. These gutters consist of eight rows of brick placed on edge crosswise of the street and two rows of stretchers, one next to the curb and the other next to the macadam. Berea sandstone and cement concrete curbing are used almost exclusively.

The crossings on macadamized streets consist of about thirty rows of Galesburg brick laid on edge crosswise of the street. This width of crossing permits the use of a higher crown and at the same time provides an easy grade. Crossings constructed upon this plan are much cleaner and interfere less with traffic than the narrow crossings.

Both brick and macadam pavements in this city are in excellent condition, although the oldest of the macadamized streets are sometimes dusty and muddy at times. The oldest brick pavement, constructed in 1893, exhibits very little wear. Chipped corners and edges are about the only evidence of deterioration. The brick pavements which have been constructed in this city have certainly demonstrated their suitability for light business traffic streets.

KEWAUNEE COUNTY.

Kewaunee county is located on Lake Michigan, in the northeastern part of the state. The kettle moraine traverses a portion of the county from northeast to southwest, giving it the irregular rolling topography characteristic of these deposits. Otherwise the county has the gentle rolling character of the old lake plane of which it forms a part.

The soils of this county are almost exclusively clayey loams of the heavier varieties. A narrow strip of sand occurs in the northeastern part of the county along the lake shore. A similar sandy strip extends southward from the center of the county.

In the northwestern corner there occur small outcroppings of Hudson River shale. With this exception the underlying rock is Niagara limestone.

The surface of the county is strewn with boulders of granitic and other igneous rocks, all of which are desirable as a material for road metal. The crushed boulders used in conjunction with the limestone from the quarries, as described in another part of this report, ought to produce excellent macadam pavements.

ALGOMA.

(Pop., 1,738.)

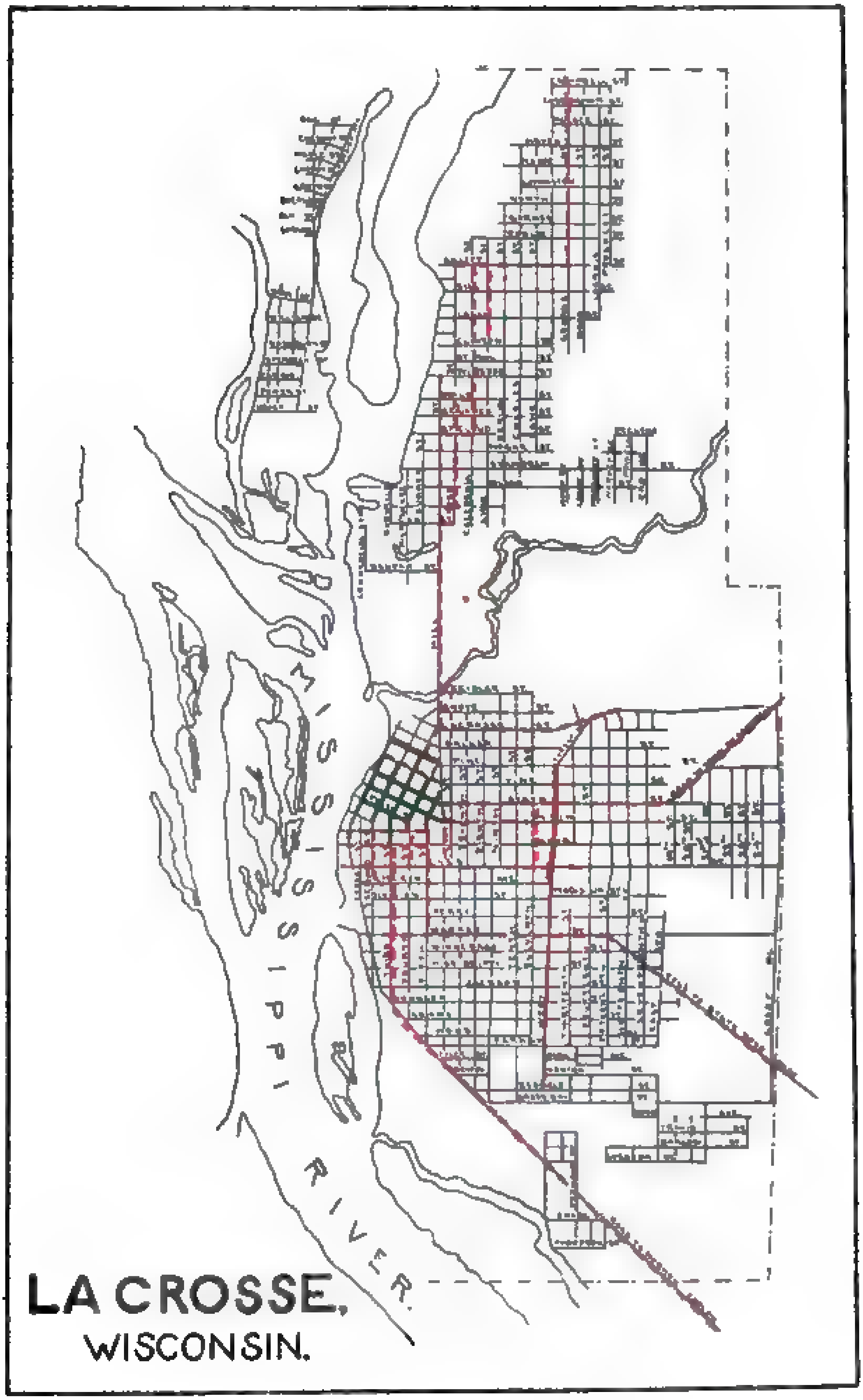
Four blocks of Steele street were paved in 1894 with cedar blocks which are reported to be in good condition at the present time. This pavement was built by bringing the subsoil to a proper grade and laying a foundation of plank on a bed of sand. On this the blocks were laid and the joints filled with sand. The curb was also built out of wood, two inch planks being used.

The other streets have been improved by the addition of gravel. The subsoil is sandy and the streets are easily kept in good condition.

There are no sewers in the city and the rain water is carried off in surface gutters.

LA CROSSE COUNTY.

La Crosse county is located in the west central part of the state on the Mississippi River. Except along the river valleys and on the tops of the ridges, the country is broken and hilly. This county is in the driftless area and consequently the topography is of the typical erosion type. Many of the roads have steep grades, increasing the difficulties of constructing pavements. Except in the southeastern part of the county, the soil is sand and sandy loam. The sand occurs



Limestone Macadam Pavements.
Quartzite Macadam Pavements.
Brick Pavements.

mainly along the La Crosse, Wisconsin and Black rivers and their tributaries. In the southern and southeastern parts of the county the soils are clayey and prairie loams. Along the La Crosse river and its tributaries occur occasional areas of humus soils composed mainly of muck and peat.

The underlying rock in the northern two-thirds of the county is sandstone of the Potsdam formation. This sandstone also outcrops along the river valleys in the southern part of the county, although the tops of the ridges are capped with Lower Magnesian limestone. An irregular tableland area in the north central part of the county is also capped with Lower Magnesian limestone.

The limestone in this county is practically the only local stone which can be obtained for improving the rural highways. This stone is of a somewhat inferior grade but, nevertheless, it will probably be used very generally on account of the expense of shipping in better stone from other localities. The local stone is unfit for use in the construction of city pavements except in foundations.

LA CROSSE.

(Pop., 28,895.)

Up to the year 1900 La Crosse had constructed about 19.6 miles of limestone macadam and not a mile of any other kind of pavement. The first of these pavements was built in 1870 and the last in 1898. The cost of their construction was about 45c. per square yard, the city furnishing the roller and doing all of the rolling. The stone was from the Lower Magnesian formation and was quarried in the bluffs near the city. The pavement was made by laying a foundation of large stones to a depth of nine inches and surfacing with a six-inch layer of fine crushed stone.

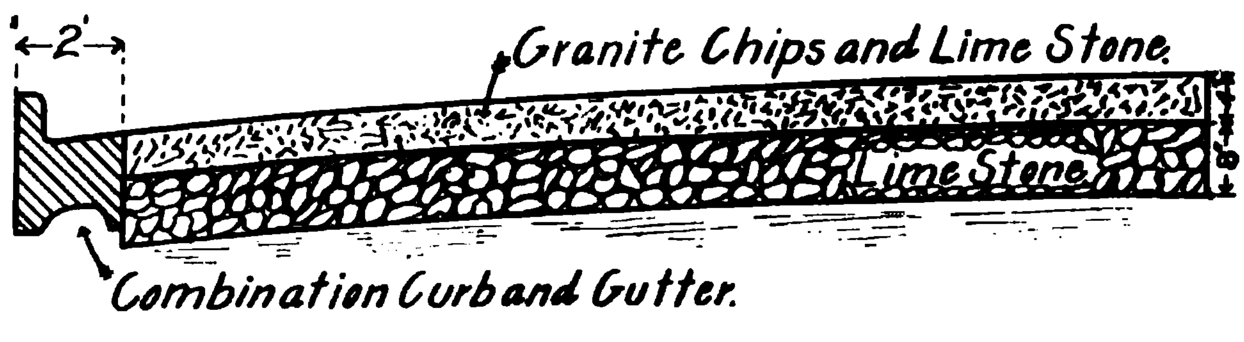
Mr. Frank Powell, city engineer, says with regard to this pavement: "The stone is entirely too soft for use as macadam. The greatest injury is caused by the weather. The stone is very susceptible to disintegration by water and changes of temperature, and this, combined with the natural wear from travel,

causes the accumulation of a vast amount of mud and dust, to say nothing of the destruction of the macadam." Mr. Powell says that the yearly cost of repairing these streets has been about $100 per mile, while the cost of cleaning is estimated at $288 per mile. With regard to these estimates he says: "The figures given for cost of repairs and cleaning are not correct for close estimating. They are calculated from the total cost of repairs and cleaning for the year 1898 and on the total mileage. A large part of this total mileage was not cleaned or repaired, although it greatly needed it. If the total mileage were cleaned and repaired when necessary, I am of the opinion that the repairing would cost at least $500 per mile per year and the cleaning as much more."

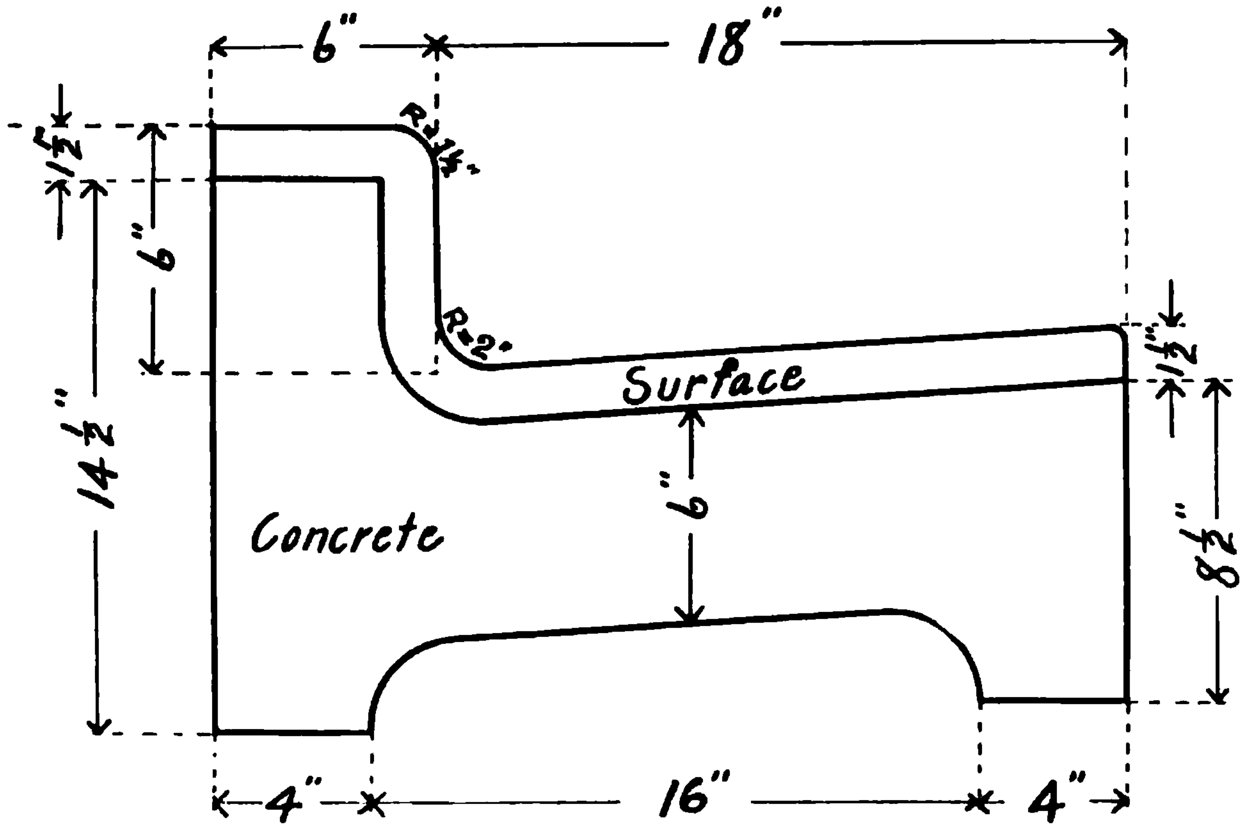
"The cost of sprinkling is not included in the above figures, but I believe that it should be, because macadam requires vastly more sprinkling than other pavements."

The accompanying map shows the streets which are still paved with limestone macadam, as well as the streets that have been paved during 1900 and 1901 with vitrified brick and granite top macadam. The following is a list of the streets which have been paved since 1899.

CROSS-SECTION OF ONE HALF ROAD-WAY



CROSS-SECTION OF COMBINATION CURB AND GUTTER



Plan of Macadam Pavement, La Crosse, Wis.

La Crosse.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction. Foundation. Kind.	Foundation. Thickness.	Surface. Kind.	Surface. Thickness.	Where material was obtained.	Average width of street between curbs	Total cost of construction.
Front	From Vine to Mt. Vernon	1900	Concrete	6 in.	Brick	4 in.	Canton, Ohio	42 ft.	
Second	From Vine to Mt. Vernon	1900	do	do	do	do	do	do	
Third	From Pine to King	1900	do	do	do	do	do	do	
Fourth	From Vine to Jay	1900	do	do	do	do	do	do	
Fifth	From State to Jay	1900	do	do	do	do	do	do	
Vine	From Front to Fourth	1900	do	do	do	do	do	do	$102,454 00
Pine	From Front to Fourth	1900	do	do	do	do	do	do	
State	From Front to Sixth	1900	do	do	do	do	do	do	
Main	From Front to Sixth	1900	do	do	do	do	do	do	
Pearl	From Front to Fourth	1900	do	do	do	do	do	do	
West avenue	From Pine to Green Bay	1901	Limestone	do	Quartzite	do	La Crosse and Devils Lake.	do	

The granite top macadam pavements, which are now being constructed on residence streets, will wear well and prove entirely satisfactory, provided the city establishes a system of maintenance by which they can be kept up. It may be well to note at this place that the stone used for surfacing is not granite but quartzite from the Devil's Lake region. Although not considered as desirable for macadam as granite or trap rock, yet the lower price of the stone may compensate in part for its less desirability.

WEST SALEM.

(Pop., 725.)

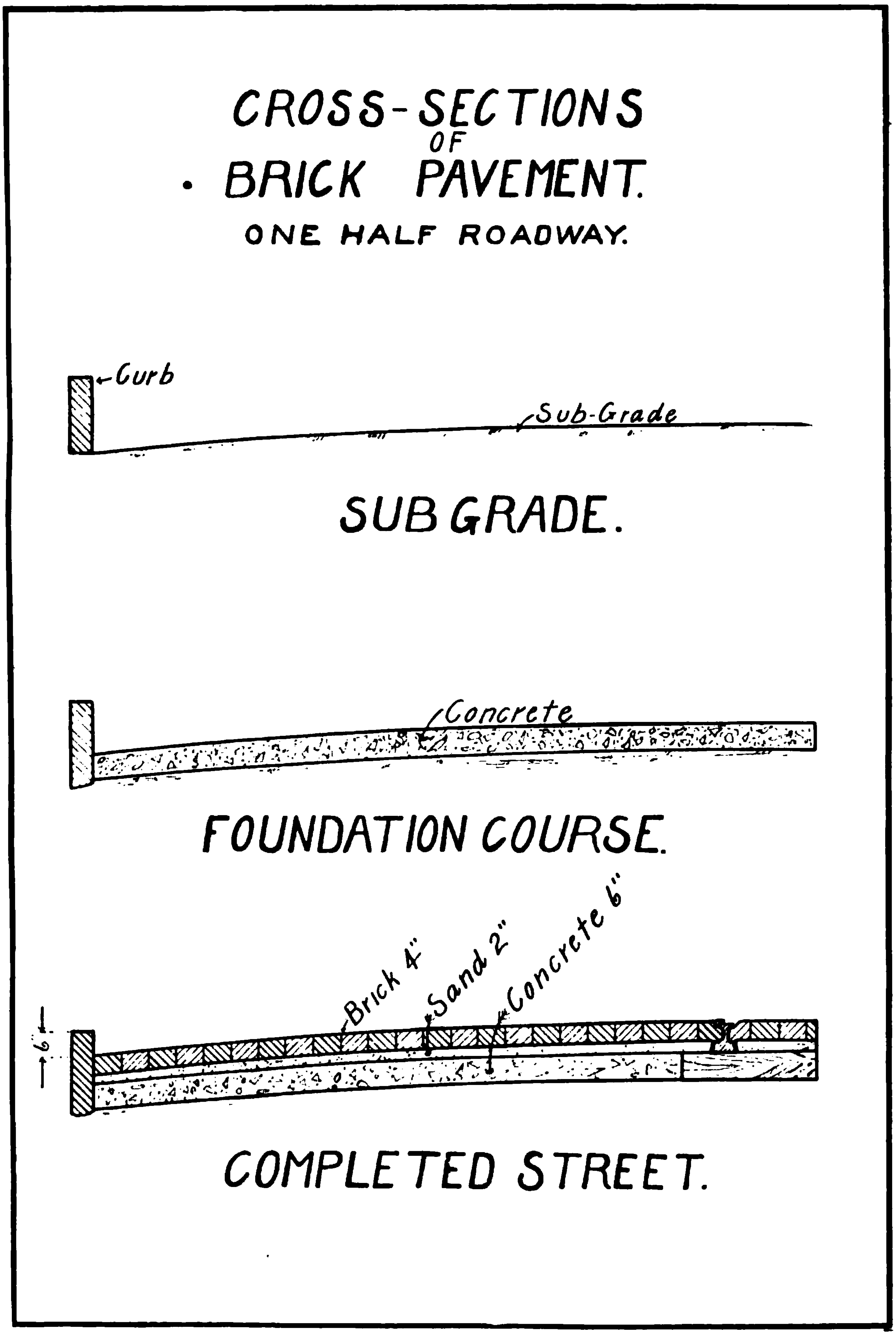
The streets in this city consist of a surface soil of black loam, underneath which occurs a clay subsoil. Up to January 1st, 1902, none of the streets were paved. During June, 1902, the city macadamized 225 feet on Leonard street and 850 feet on Main street, with limestone macadam. The surface water is carried off in stone gutters. The streets are perfectly level, and unless the pavement is kept in good condition and well crowned, the water is liable to settle in pools.

LA FAYETTE COUNTY.

La Fayette county is located in the southwestern part of the state. The land consists of alternating flat topped ridges and river valleys. The Pecatonica river with its tributaries, breaks the land up into a series of ridges and hills which gives the surface a somewhat hilly topography.

The soil in this county is almost entirely clayey loam of the lighter and medium varieties. The lighter varieties of loam are found along the river valleys and the heavier on the tops of the ridges. This county lies within the driftless area and therefore contains no gravel or foreign boulders such as are found in the eastern part of the state.

The ridge land portions of the county are mainly capped with Galena limestone. The streams, however, have cut their channels deep enough to expose, in places, the Trenton limestone, St.



Plan of Brick Pavement, La Crosse, Wis.

Peters sandstone and Lower Magnesian limestone. In the northwestern part of the state occur two hills on the sides of which Hudson River shale and Niagara limestone are exposed. The hard beds of the Galena limestone offer the most promising rock for road metal. A detailed examination of these rocks will undoubtedly show certain beds that are fairly well adapted for road metal for the rural highways.

LANGLADE COUNTY.

Langlade county is located in the northeastern part of the state. The surface of the county is covered with glacial drift on account of which the topography is more or less rolling and hilly. The soil is mainly a light clayey loam with occasional irregular areas of humus soils composed mainly of muck and peat. Adjacent to some of the stream channels in the eastern and western parts of the county, the soil is a sandy loam.

The surface of this county has been greatly modified by glacial erosion and deposition. The terminal moraine of the last glacial epoch extends through the county in an irregular northeast-southwest and northwest-southeast direction, and is represented by a series of ridges and hills of boulder clay, gravel and sand. The boulders which are strewn over the surface and the gravel which occurs in the hills and ridges constitute a very valuable source of material for the improvement of the highways. The boulders, or "field stone" as they are often called, are now being used by Antigo as will be seen by the following the descriptions of the pavements in that city.

This county is underlain by granitic and gneissoid rocks belonging to the pre-Cambrian formations. These rocks outcrop in many places over the county where they can be easily quarried and crushed as desired. A proper appreciation of the value of broken stone pavements by the people of this county will lead to a more general use of these igneous rocks.

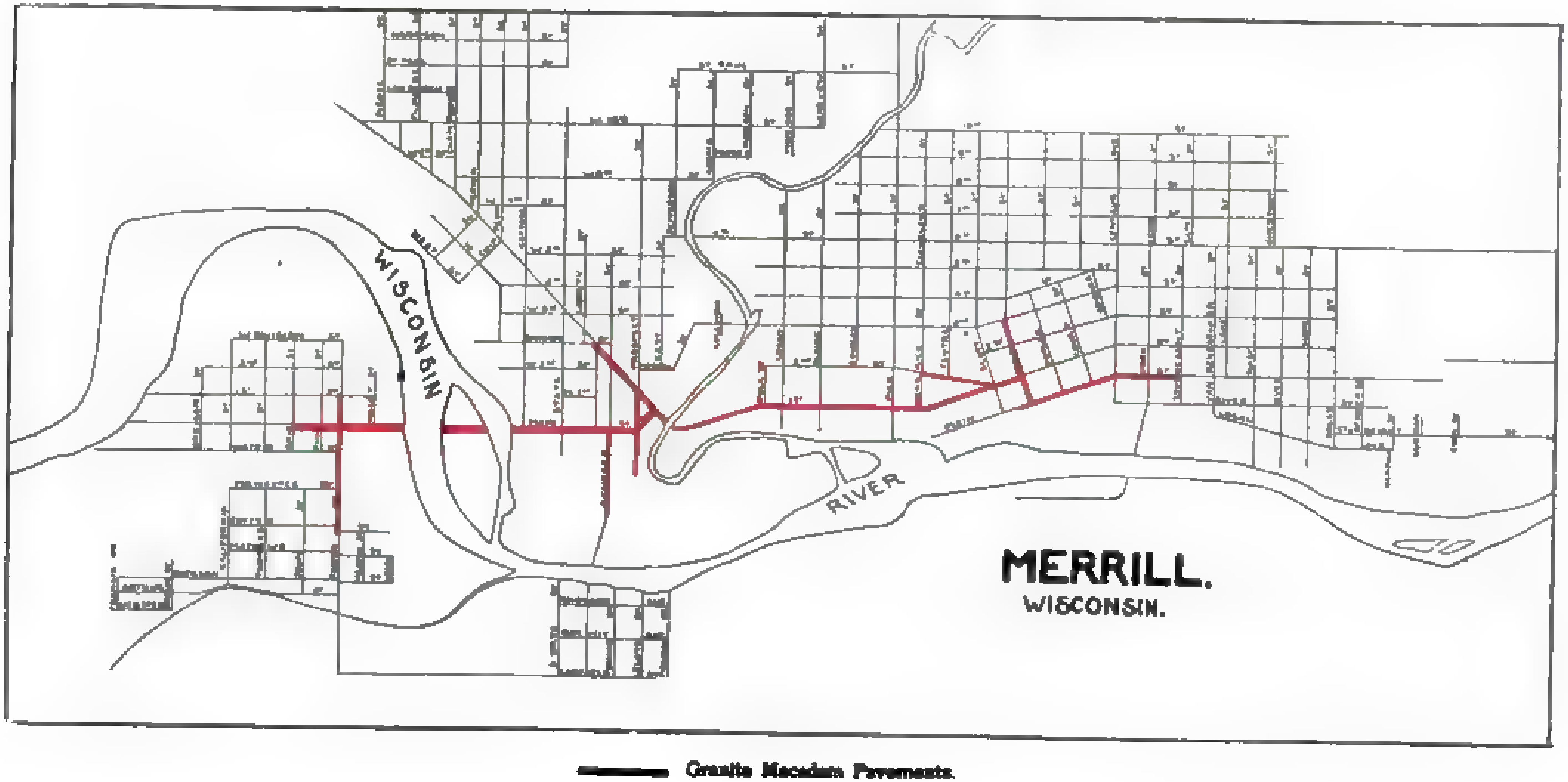
ANTIGO.

(Pop., 5,134.)

The only kind of pavement constructed in Antigo is macadam. Main is the only street that has been paved. The first section of this pavement was constructed in 1897, being open for traffic in the month of September. The second section was constructed in 1898 and was opened for traffic in September of that year. This pavement extends for a distance of five blocks or one-fourth of a mile. The subsoil in this city is a clay and sandy loam which will ordinarily support any pavement which is built above it. The paved street is 64 feet wide between curbs, and of this width 52 feet has been macadamized. The remaining six feet on each side has been left for gutters. The macadam on this street is 10 inches thick at the crown and 6 inches at the gutter. The road bed has a crown of 12 inches. The gutter is constructed out of cobble stones.

The stone used in constructing the macadam consisted of field stone purchased from the farmers. In this region the field stone consists mainly of granite and trap rock. The stone is broken in a crusher, screened and laid on the street in two courses. The first, or foundation course, consists of No. 1 crushed rock six inches in thickness; the second course consists of No. 3 crushed rock four inches in thickness. That portion of the pavement extending 700 feet east from the railroad track, was constructed by the city at a cost of 44 cents per square yard. The macadam east from the west side of Clairmont was built under contract to the lowest bidder and cost 56 cents per square yard.

Mr. B. F. Door, the city engineer, to whom I am indebted for this information, informs me that the contract price was too high and that the pavement can be constructed cheaper by the city than when let out to the lowest bidder. Mr. Door recommends the construction of cobble stone gutters, remarking that the horses cannot make holes in them by stamping while fighting flies, as they often do where the macadam is built up to the curb. This suggestion by Mr. Door is a good one. I believe that the gutters should be wide and that either cobble stone,


WISCONSIN
RIVER
MERRILL.
WISCONSIN.
Granite Macadam Pavements.

flag stone, stone block, cement or brick should be used in their construction. Stone block, brick or concrete are preferable.

Mr. Door's experience leads him to believe that no field stone should be purchased which is less than 4 inches in its smallest diameter. This may be a wise precaution, since it provides against the use of pieces which have been partly rounded. However, where field stone are scarce, I would not consider this necessary. He further says that the road bed should be made hard and smooth by thorough rolling and that the traffic should be entirely removed until the pavement has been entirely finished.

To prevent raveling he recommends sprinkling the pavement thoroughly in dry weather.

A letter from the city clerk on September 15th, 1900, states that the macadam pavements constructed in '97 and '98 are in perfect condition and that the cost of cleaning does not exceed $10.00 per year.

The only observation which I have to make with regard to the pavement in this city, is that the crown is probably unnecessarily high. To keep the pavement in as good condition as it is today will need careful attention to repairs. It is costly to allow a pavement to deteriorate to such a degree that the only method of repairing is reconstruction.

LINCOLN COUNTY.

Lincoln county is located in the north central part of the state. The surface is rolling and hilly as a result both of stream erosion and glacial deposition. The soils are mainly light, clayey loams, although a heavier variety occurs in the southwestern part. Adjacent to the Wisconsin river and along the tributary streams from the east, the soils are sandy loams and sand. This sand belt which is a part of the Wisconsin river valley throughout most of its course, widens in the northern part of Lincoln county into a delta shaped area which covers a large part of Vilas, Onedia and Iron counties to the north. The southern three-fourths of the county is covered with a thin mantle of drift as a

result of the earlier advances of the glacial ice sheet. The last advance of the ice covered only the northern one-fourth of the county, but left very heavy deposits of boulder clay, gravel and sand. The front of this advance is marked by ridges and hills of sand and gravel such as characterize the terminal morainal areas.

This county is underlain almost entirely with granitic and gneissoid rocks such as characterize the pre-Cambrian formations. Rocks of the trap variety are found in numerous places, although they are not as abundant as the rocks of the granitic type. The land surface in this county is in many parts thickly strewn with boulders of granitic and trap rocks, as a result of glacial deposition. These boulders, as well as the outcrops of granitic, gneissoid and trap rocks, furnish an inexhaustible supply of excellent stone for road metal.,

MERRILL.

(Pop., 8,537.)

All of the pavements in Merrill are granite macadam. The first macadam pavement was laid in 1897 and in the following year about half a mile additional was constructed. In 1900, the improvements were continued as shown by the following table.

Macadam Pavement, Merrill, Wis.

Rock Crusher and Bins, Merrill, Wis.

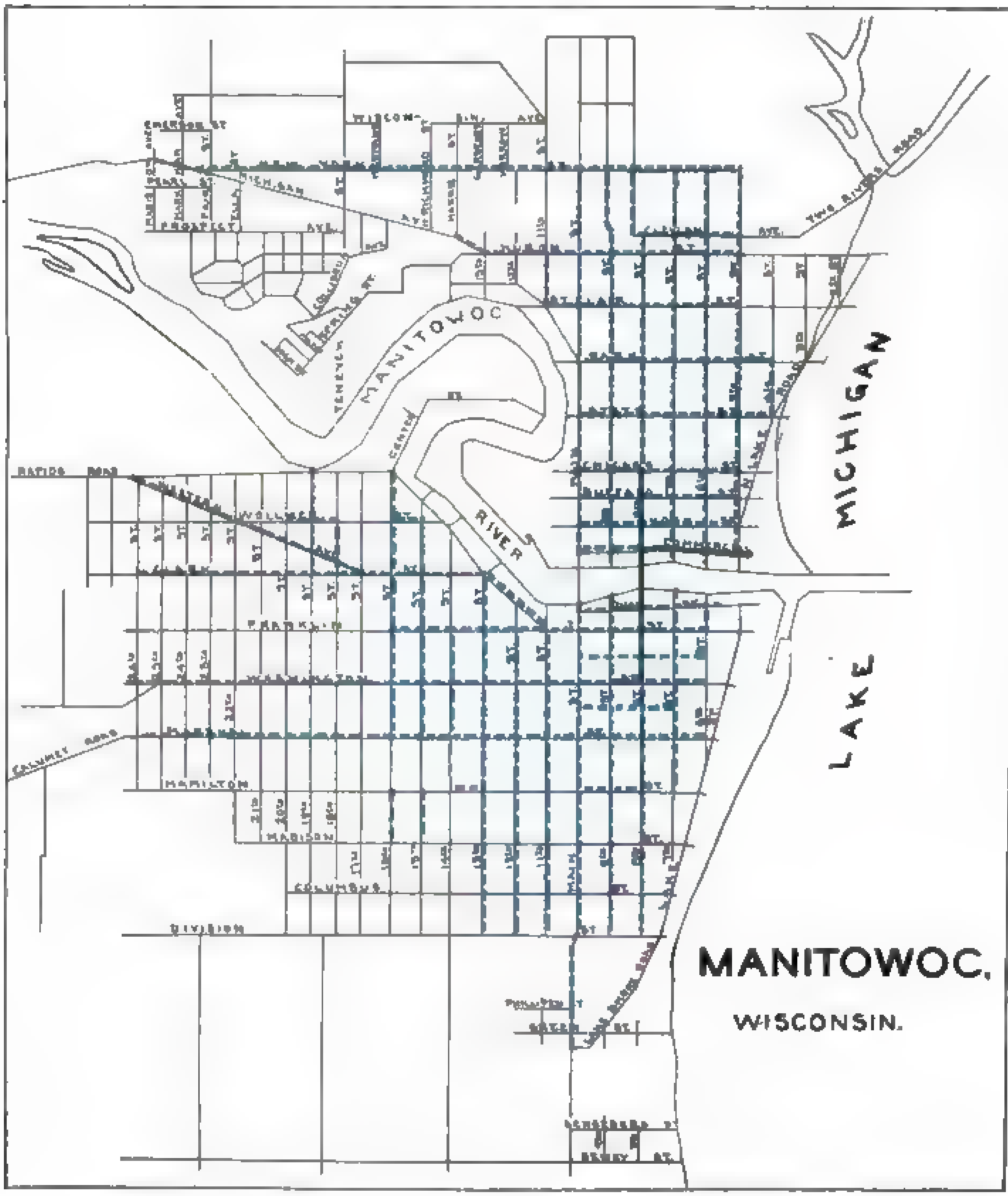
Merrill.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction.				Where material was obtained.	Average width of street between curbs.	Cost of construction per sq. yd., exclusive of curb, gutter and underground pipes.
			Foundation.		*Surface.*				
			Kind.	Thickness.	Kind	Thickness.			
Main	From Mill to Scott (½)	July, 1900.	No. 1 cr'sh'd granite.	6 in.	No. 2 and 3 cr'sh'd granite	2 in. 1 in.	Local	49 ft.	$0.60 to 80
Main	From Mill to Poplar (½)	July, 1900.	do	do	do	do	do	49 ft.	do
Main	From Centre to Park (½)	Aug., 1900.	do	do	do	do	do	49 ft.	do
Main	From Park to Stuyvesant	Sept., 1900.	do	do	do	do	do	49 ft.	do
Mill	From Main to 1st (¾)	July, 1900.	do	do	do	do	do	46 ft.	do
First	From Mill to Scott	July and Aug., 1900.	do	do	do	do	do	46 ft.	do
First	From Scott to Center	Aug., 1900.	do	4 in.	do	do	do	46 ft.	do
Second	From Scott to Center	Aug., 1900.	do	6 in.	do	do	do	46 ft.	do
Second	From Center to Hendricks	Aug., 1900.	do	do	do	do	do	46 ft.	do
First	From Center to Hendricks	Aug. and Sept., 1900.	do	do	do	do	do	Strips 30 ft. wide in center of St., no curbs used.	.40 to .60
Prospect	From W. Main to Grand Ave.		do	do	do	do	do	40 ft.	.40 to .60
Main	4 blocks	June, 1897.	Coarse granite.	4 in.	Medium and fine granite.	1 in.	do	Business 46 and residence 30	.90
West Main	3 blocks	July, 1897.	do	do	do	do		Business 46 and residence 30.	
Ellis Court	1 block	Sept. and Oct., 1898.	do	do	do	do			
Grand Ave	1 block	Sept. and Oct., 1898.	do	do	do	do			

The city owns a crushing plant and buys field stone from the farmers, paying $2.00 to $2.25 a cord. The pavements in this city are among the best type of macadam in the state. The subsoil, in most parts of the city, is sand and gravel. In some places the streets have been covered with shavings and sawdust to keep down the dust. The street is given a crown of from six to ten inches, depending upon its location. Part of the streets are provided with cobble stone gutters, while plank curbing has been used on all streets. The total thickness of the macadam is from six to eight inches. The stone is laid in three courses, each of which is flushed with water and thoroughly rolled before the next is added. Mr. F. E. Mathews, city engineer, to whom I am indebted for this information, says: "That barring the curbs and gutters, I think we have reached perfection in road making." Mr. Mathews believes that all of the streets where horses are tied should be provided with cobble stone or other gutters as a protection to the pavement. He also recommends the use of a different curb from plank. These suggestions which Mr. Mathews makes regarding the Merrill pavements, are sound and I believe that the city should lay no more plank curbing and that in planning the construction of future pavements provision should be made for stone, brick or cement gutters. I believe that along all but the business streets, a gutter similar to that used in Baraboo and illustrated in this report, will prove most satisfactory. The width of the macadam on residential streets should not exceed 30 feet, unless the traffic is very heavy. The remaining portion should be sodded and parked as described in another part of this report. Finally if it is expected to obtain the best service from the macadam pavements, the city should establish a system of maintenance.

MANITOWOC COUNTY.

Manitowoc county is located in the east central part of the state on Lake Michigan. The surface of the county is somewhat diversified, being broken up into hills, ridges and prairies by the glacial deposits and present stream channels. The



Brick Pavements.

Gravel Streets.

county is almost wholly within the area occupied by the lacustrine clays and heavy clayey loams. Covering a narrow belt extending along the lake and north into Kewaunee county, the soil is a sandy loam. Throughout the county there occur occasional irregular deposits of humus soil composed mainly of muck and peat.

This county is entirely underlain with Niagara limestone which outcrops in numerous places throughout the area.

The central part of the county beyond the area of lacustrine clays is occupied by a glacial moraine composed of boulder clay, sand and gravel. This section of the county is strewn with large quantities of granitic and trap rock boulders, which constitute a valuable supply of rock for road metal. There is probably sufficient field stone in the central part of the county to macadamize all of the important highways in the county. As suggested in other parts of this report, macadam pavements can be built most cheaply by using limestone for the foundation and granite or trap rock for the surface.

MANITOWOC.

(Pop., 11,786.)

Up to the year 1900 the only improvements made to the streets of this city were through the addition of gravel. To give a correct idea of the manner in which these improvements were made I can do no better than to quote from a letter written to me by the city engineer, Mr. Louis K. Pitz. He says: "All improved streets are graveled. The gravel is placed directly upon the natural soil as the grading lays the same open. The roadways are from 36 to 50 feet wide and the thickness of the gravel is uniformly six inches. The gravel has never been screened, being used directly from the gravel banks, which are abundant in this vicinity. At one time the specifications called for gravel which would pass through a 2-inch ring. This has been changed and any stone up to 5 inches in diameter can be used."

"The subsoil is almost uniformly sand. Since the domestic sewer system has been extended the sub-drainage over two-

thirds of the gravel streets has been very good. We have some very excellent and some very poor gravel streets. Our gravel consists principally of limestone pebbles well rounded by the action of water or the glaciers. Some of the deposits contain more or less clay, while others are very clean and contain quite distinct layers of sand."

"Limestone gravel is a poor material for streets. It is too soft, wearing very fast under the wheels of all kinds of vehicles, causing the streets to be very dusty in dry and muddy in wet weather. As a rule it may be said that the clean gravel, that is, gravel which contains no clay, makes a better wearing street than the clay gravel, although the latter makes a smoother surface in a shorter time."

"About a year ago the city purchased a twenty-ton roller and by using this several attempts have been made to better our streets. Some of the streets which we made had a more uniform surface, but I will state that *it takes better material to make better streets.*"

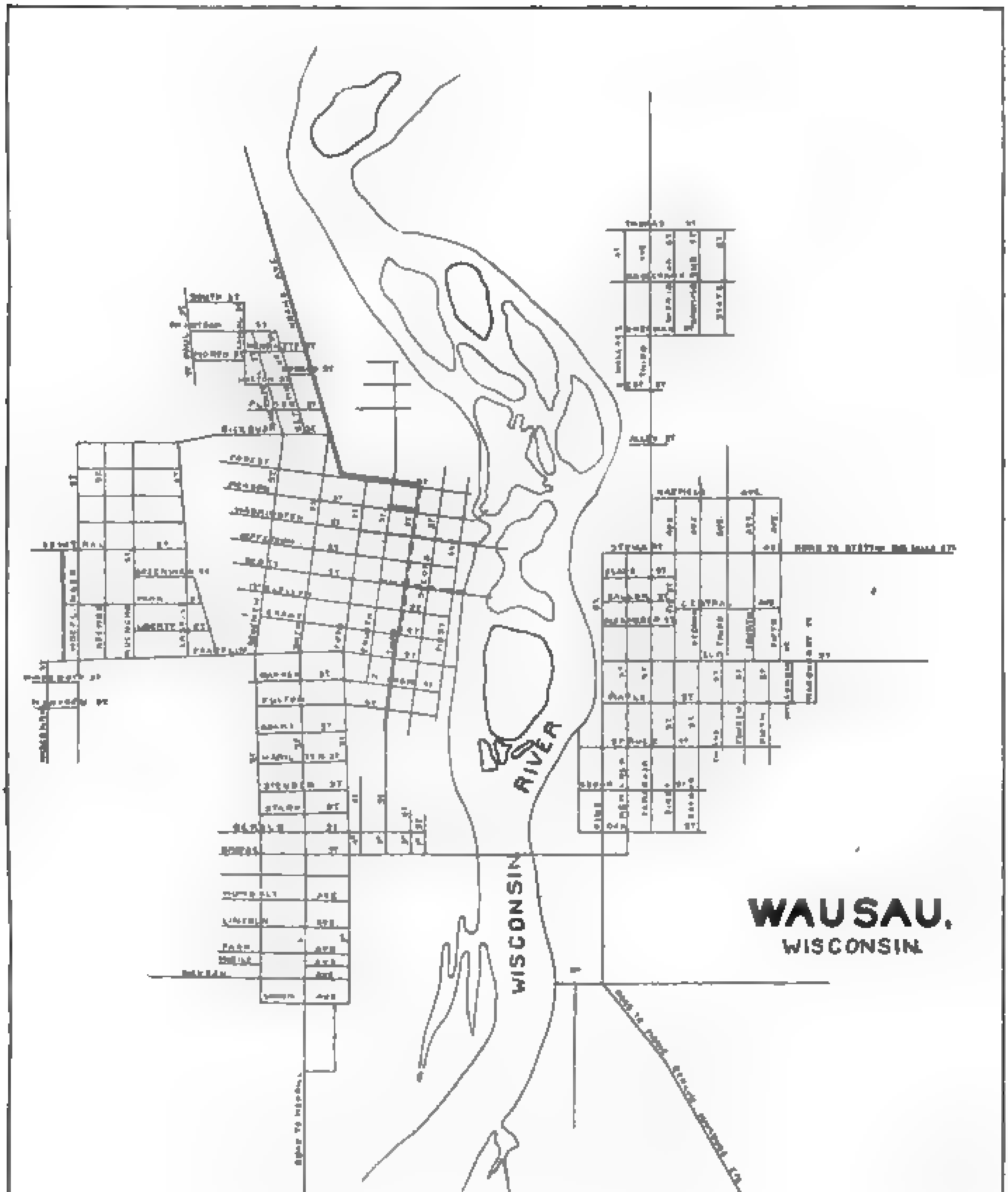
"We are now using some crushed stone, a mixture of limestone and so called 'nigger heads' which consist mostly of granite. With this material we have obtained better results."

"The cost of making a mile of gravel streets, as above described, is about $3,000. The yearly cost of repairs is not less than $150 per mile outside of cleaning, which is estimated to be $200 a mile in the denser portions of the city."

"In conclusion I will say, that our gravel streets are good where traffic is light and bad where traffic is heavy, and nothing will better this condition but better material."

It is thought that the above is a fair statement of the condition of the highways in Manitowoc up to the year 1900. During 1900, the city constructed about three-quarters of a mile of vitrified brick pavement on 8th and Commercial streets. The brick were laid on a concrete foundation and in other respects the pavement was made to conform to the usual type constructed in Wisconsin.

The pavements on the residential streets should be macadam with a wearing surface of granite or trap rock. Brick for the



Cedar Block Pavements.

Granite Macadam Pavements

business and granite top macadam for the residence streets with a proper system of maintenance, will give this city the kind of pavements best suited to the present traffic conditions.

TWO RIVERS.

(Pop., 3,784.)

Gravel and clay are the only materials that have been used to improve the sandy streets of Two Rivers. Mr. A. B. Leyse, who was city clerk in 1899, wrote that it had been customary to cover the streets with a layer of clay from two to six inches in thickness, adding to this about six inches of gravel. In 1899, the city substituted broken limestone for gravel, believing that it was not only less expensive but also made a better street.

Main, Washington and Walnut streets have been repaired in this way. Walnut street, which is 40 feet wide between curbs, was repaired in 1898 for a distance of 460 feet at a cost of $197. The repairing of this street required 2,340 cubic yards of excavation, 356 yards of clay filling and 356 yards of gravel surfacing.

The above indicates that the cost of repairing a street upon this plan is very little. There is an abundance of limestone and gravel in the immediate vicinity and there is little reason why the streets should not be kept in excellent repair.

It is thought that macadam pavements, with a proper system of maintenance, would be less expensive and more satisfactory than the present character of improvements.

MARATHON COUNTY.

Marathon county is located in the central part of the state. The topography of the county is somewhat irregular, consisting of ridge land areas trenched by the valleys of rivers and tributary streams. The soils are mainly clayey loams of the light and medium varieties. Belts of sand and sandy loam follow the valleys of the Wisconsin river and its tributaries into most parts of the county. The most extensive areas of sand occur east of the Wisconsin river.

This county is covered with glacial drift. The earlier glaciers traversed the entire county, leaving a thin mantle of boulder clay. East of the Plover river, in the southeast corner of the county, occur heavy deposits of drift, resulting from the last ice incursion. These deposits constitute a portion of the terminal moraine and consist of ridges and mounds of boulder clay, sand and gravel.

The county is strewn with field stone of the granitic, gneissoid and trap varieties which constitutes an inexhaustible supply of excellent stone for road metal.

The county is underlain with granite, gneissoid, quartzite and trap rock, which outcrop in nearly all parts of the county. There is considerable difference in the value of these different varieties of stone for road metal, and a careful examination of the different outcrops, with tests of the stone, would assist very materially in the determination of their relative value.

ATHENS.

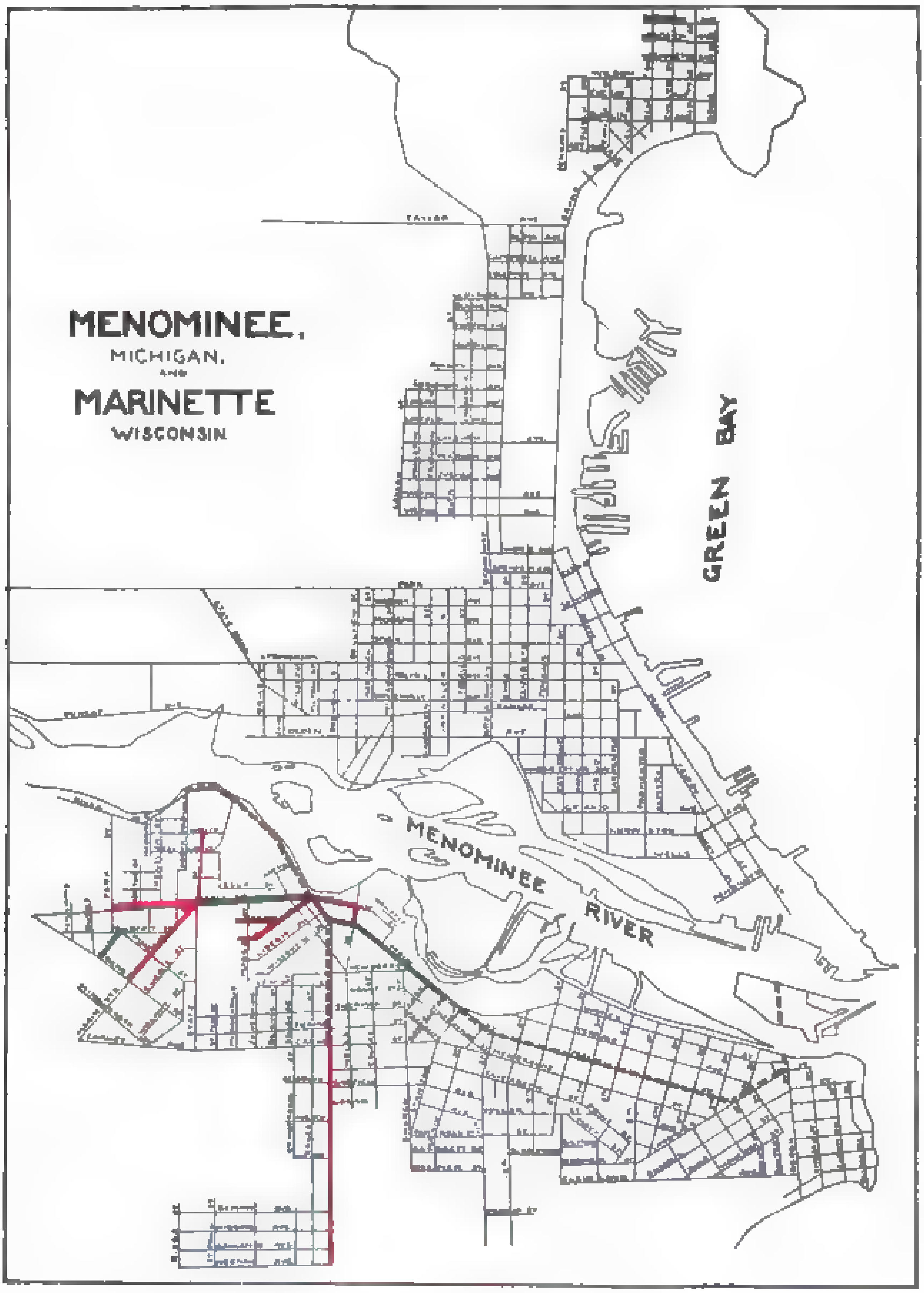
(Pop., 400.)

The streets of Athens have been improved with gravel which occurs in considerable quantities very near the city. Near where the railroad crosses the river there are large outcrops of trap rock, granite and gneiss. Trap is an excellent rock for macadam but the gneiss is not as well suited for this purpose. There are also large quantities of granite and trap rock boulders on the farms which constitute an unlimited supply of desirable stone for road metal. Either the boulders or the trap rock would make excellent material for constructing macadam pavements.

WAUSAU.

(Pop., 12,354.)

The streets of Wausau have been improved by the construction of both cedar block and macadam pavements. The city had in January, 1901, about fourteen blocks of cedar block pavement and about fifteen blocks of granite macadam. The cedar block pavement, which was laid eight or ten years ago, is in



Cedar Block Pavements.
Macadam Pavements.
Brick Pavements.

poor condition and in a few years should be replaced with either brick or macadam.

The subsoil about Wausau is largely sand and gravel except in low places, where shavings, saw-dust and pine slabs have been used for filling. The streets are about 34 feet wide and the macadam pavements are made about 20 feet wide. The city owns a crusher and roller and purchases field stone from the farmers. Wherever the macadam is constructed the full width of the street it is customary to build a curb and gutter, otherwise the gutter is usually omitted. The macadam is not well rolled and enough attention is not given to the surface drainage. The city has no system of maintenance and the weeds and grass are allowed to choke many of the gutters, making the streets look untidy. With well constructed gutters and a correct system of maintenance Wausau might easily have the best of pavements. The city is situated in the midst of a region well supplied with the very best material for macadam pavements. Both the residence and business streets should be improved with permanent pavements. It may be advisable to pave the business streets with vitrified brick or granite blocks, but the residence streets should be paved with the much less expensive macadam.

The sidewalks are constructed largely out of plank, very little cement or flag stone having been thus far used.

MARINETTE COUNTY.

Marinette county is located in the northeastern part of the state on the Menominee river. The northern and central sections of the county have a rough and rugged surface resulting from stream erosion combined with glacial erosion and deposition. The southern part of the county bordering on Green bay is low and marshy.

The soil in the southwestern part of the county is largely clayey loam. North and west of Peshtigo harbor is a tract of land which is covered with sand. The northern two-thirds of the county is largely underlain with sand and sandy loam. A small belt in the western part of the county and another in the

northeastern part have a soil of clayey loam. Many parts of the county are covered with a considerable thickness of glacial drift. The underlying rocks, which are of granitic, gneissoid and trap varieties, are found outcropping in many parts of the county.

Igneous rocks suitable for road metal are found in most parts of the county either in outcrops or as boulders at the surface. So abundant are the granitic and trap rocks in this county, that there ought never to be any shortage or road metal. The rubble stone and spalls from the quarries at Amberg and Athelstane ought to be used by the county in the improvement of the highways.

MARINETTE.

(Pop., 16,195.)

Up to January the 1st, 1901, Marinette had 4½ miles of cedar block pavement, 19,511 square yards of vitrified brick and 3,114 square yards of limestone macadam. The following is a list of the streets paved.

Street Improved with Sawdust and Shavings, Eleventh Street, Marinette, Wis.

Marinette.

Name of street.	Part paved, macadamized, etc.	Date	Materials Used in Construction.				Where material was obtained.	Average width of street between curbs.	Cost of construction per sq. yd. exclusive of curb, gutter, and underground pipes.
			Foundation.		*Surface.*				
			Kind.	Thickness.	Kind.	Thickness.			
Main	All.	1899			Cedar bl'ks.	6 in.			
Hall avenue	Business part	1899			do	do			
Pierce avenue	1½ miles	1891			do.	do			
Riverside	1 mile	1891			do.	do			
John and Depot streets.	3,114 sq. yds	1900	Limestone.	5 in.	Limestone.	4 in.	Duck Creek, Wis.	20 ft.	$0.45 per sq. yd.
Hall Ave., Dunlap Square and Main street	19,511 sq. yds	1900	Macadam.	6 in.	Vitrified brick.		Galesburg, Ill.	About 60 ft	1.75 per sq. yd.

The first cedar block pavement was constructed in 1889 and is in an almost impassable condition today. The cedar block pavement laid in 1891 is on a residence street and is in fair condition. Mr. J. W. Follett, to whom I am indebted for this information, said, in 1899, that the main business streets which were paved with cedar block were at that time completely worn out. The pavements which were laid in 1891 on Pierce and Riverside avenues, residence streets, were in good condition in 1899. In 1900 the city began paving with brick and macadam, using the former for business and the latter for residence streets. Hall avenue and Main street, on which the cedar block pavement in 1899 was reported to have been in such a dilapidated condition, were paved with Galesburg brick, laid on a 6-inch macadam foundation.

The subsoil in this vicinity is largely sand and gravel, except in places where saw-dust and shavings have been used to keep down the dust or fill low marshy spots. The sandy subsoil is admirably adapted to the construction of macadam pavements and permits the substitution of four or five inches of macadam for the 6-inch concrete foundation which a softer subsoil requires.

The brick pavement on Main street and Hall avenue was carefully examined during the summer of 1901 and the only deterioration observed was a chipping of the edges and corners. The pavement contains some underburned and overburned brick, showing that they had not been subjected to a sufficiently rigid inspection. The joints are filled with sand instead of cement grouting, as they should have been. The street is practically level, and it should have been made as smooth and watertight as possible. Filling the joints with cement grouting would have preserved the edges and corners on many of the brick which are now chipped.

Berea sandstone curbing has been used on Main street. On the macadamized streets neither curb nor gutter has been constructed. Most of the walks in this city are built out of wood. Cement concrete is used only on Main street.

The macadam pavements are about 20 feet wide, which is

Granite Quarry. Montello Granite Company, Montello, Wis.

very narrow when compared to those constructed in other cities. The pavements have been given a high crown and the earth gutters on either side are relatively deep. If granite or trap rock had been used in place of limestone for the wearing surface of these pavements and cement gutters added to carry off the water, one would consider them almost ideal pavements for the streets on which they have been built. The macadam is sufficiently wide to accommodate all the traffic which it will be called upon to sustain, and more than this would be useless and expensive. In improving other residence streets in this city, it will be profitable, both from the standpoint of construction and maintenance, to make the pavements the same width and shape as on John and Depot streets.

I cannot close this discussion without suggesting that in the construction of macadam pavements in the future, granite or trap rock be used in place of limestone. An abundance of excellent granite can be obtained at the Amberg quarries or from outcrops of granite even nearer to the city. With the close proximity of excellent stone for building macadam pavements, provision ought to be made to use granite instead of limestone at least for the wearing surface. The cost of construction may be somewhat higher but this will be more than compensated for by the lessened cost of maintenance and greater freedom from mud and dust. Under any circumstances the city should inaugurate a system of maintenance by which the macadamized streets will always be kept in good repair.

PESHTIGO.

(Pop., 1,719.)

The street improvements in the village of Peshtigo have included merely grading and graveling. The streets are subject to a very light traffic and are more in the nature of country highways than city streets. It is reported that the gravel, which occurs in abundance in this vicinity, makes a very good street.

The abundance of granite and trap rock in this region leads me to suggest that it might be as economical to purchase a crusher and construct macadam pavements as to gravel the

streets each year. Macadam pavements would certainly increase the attractiveness of the village and would require much less attention than the graveled streets now used.

MARQUETTE COUNTY.

Marquette county is located in the south central part of the state. The surface of the land is somewhat irregular and rolling as a result of stream erosion and glacial erosion and deposition.

The county is covered with a mantle of glacial drift and in the western part is traversed by the terminal moraine of the last glacial epoch. The surface is covered mainly with a sandy loam, through which occur irregular areas of humus soils composed mainly of muck and peat.

The main underlying rock is sandstone of the Potsdam formation. At Montello and at two or three other localities in the south half of the county, there are hills of granite and porphry. Both of these rocks constitute an excellent road metal,—the best obtainable in this part of the state. Boulders of granite and trap rock occur in the terminal moraine of the western part of the county and constitute another source of supply for road metal.

MILWAUKEE COUNTY.

Milwaukee county is located in the southeastern part of the state on Lake Michigan. The surface is generally level except where valleys have been cut by stream erosion. The soils are mainly clayey loams of a medium or heavy variety. This county has been glaciated but was later covered with lacustrine deposits laid down by a former extension of Lake Michigan. A small area in the northeastern part of the county is underlain by Hamilton cement rock and Lower Helderberg limestone. Otherwise the underlying rocks in this county are Niagara limestone.

The Niagara limestone has been used very extensively in this county for building macadam pavements. Outside of the city gravel has constituted the principal material for the improve-

ment of the highways. The beds of hard Niagara limestone furnish some of the best road metal of any of the limestone in the state. It is not durable enough for city pavements and when so used should constitute merely the foundation, being covered with a wearing surface of granite or an equally durable rock.

On the accompanying sheet will be found a list of the streets which have been improved in Milwaukee.

MILWAUKEE.

(Pop., 285,315.)

The total length of all streets in Milwaukee, January 1st, 1900, was 521.042 miles, of which 310.924 miles were improved. Of this number 234.031 miles have been improved by grading, graveling and covering the surface with crushed limestone; 51.126 miles have been paved with wooden blocks; 8.711 miles with stone blocks; 2.649 miles with vitrified brick; 13.897 miles with asphalt; and .45 miles with telford macadam. The total length of streets paved, exclusive of those improved by grading, graveling and covering the surface with crushed stone, is 76.893 miles.

The accompanying table contains a list of all the streets which have been paved with stone block, brick and asphalt up to January 1st, 1901. It was considered unnecessary to include in these tables a list of the streets paved with cedar blocks, in view of the fact that it is the purpose of the city to replace these pavements with brick, stone block or asphalt as soon as possible. No careful record has been kept of the streets improved with macadam and telford pavements. It is expected, however, that some of the cedar block pavements will be replaced with macadam, especially where these streets are in the residence section of the city.

During the year 1900, a total of 29.637 miles of streets and alleys were improved at a total cost of $542,595.05. Of this amount $321,961.25 was assessed against the abutting property.

The following shows in detail the cost of the different items in the street and alley improvements for the year 1900.*

71,770	cubic yards excavation and 13,171 cubic yards filling	$23,284 37
26,812.78	cubic yards crushed stone and gravel	33,135 78
116,711.03	square yards asphalt paving	253,066 74
31,334.40	square yards brick paving	64,642 59
3,342	square yards granite paving	9,016 55
8,149	square yards cedar block paving	5,541 47
31,646.82	square yards alley paving	30,384 18
15,921	square yards alley repaving	2,644 16
8,469	square yards gutter paving	9,918 85
37,445	square yards gutter repaving	5,249 26
155,884.01	lineal feet stone curbing	73,756 62
10,667.85	lineal feet stone curbing reset	1,276 07
32,565.94	lineal feet cement curbing	11,704 61
13,911.57	lineal feet cement sidewalk	10,778 58
21,937.50	lineal feet sidewalk planking	6,123 37
	Total	$542,595 05

The brick thus far used have been laid on a six inch concrete foundation and the following makes have been tried: Nelsonville, Buckeye, Athens and Poston. Mr. Poetsch, the city engineer, in his report says, that although the brick pavements are more noisy than asphalt, they are nevertheless liked by a great many people on account of giving a better foothold to horses. He further adds, that this pavement should be laid on streets where the grade exceeds four feet in one hundred feet, in preference to asphalt.

No more cobble or boulder stone pavements will be laid in Milwaukee if the plan of the present city engineer is carried out. Dressed limestone blocks laid on a gravel foundation and brick blocks laid on concrete will hereafter take their place. The brick pavement makes a much better looking street and is altogether more satisfactory than the limestone block.

The city engineer says, that the cause for such extensive repairs on the asphalt pavements is due to the concentration of the traffic along these streets. He further observes that as the num-

*From the Annual Report of the City Engineer.

Asphalt Pavement. Grand Avenue, Looking East from Eleventh Street, Milwaukee, Wis.

ber of smooth paved streets increase, the traffic will become more evenly distributed and the wear less.

The report of the city engineer shows that the combined cement curb and gutter and cement sidewalks are increasing in favor and that the construction of permanent sidewalks has greatly increased. He says: "The plank walks have been very expensive to the city, in the way of damages from accidents, and in my opinion the time will soon arrive when no more plank walks should be laid upon the public streets."

The cost of street sprinkling during the year 1900 amounted to $73,019.51. The greater part of this cost was assessed against the abutting property owners. The cost of cleaning streets and alleys and removing ashes and rubbish amounted to $175,592.52. The total cost of sweeping the paved streets was $25,680.04. The following statement shows the various items in the cost of maintaining the streets during the year ending December 31, 1900.*

Labor and teaming, cleaning streets	$65,603 70
Labor and teaming, cleaning alleys	16,295 72
Labor and teaming, repairing streets	45,874 92
Labor and teaming, repairing alleys	6,283 03
Labor and teaming, removing ashes and rubbish	94,693 10
Labor, repairing sidewalks and crosswalks	8,080 80
Labor, removing snow from sidewalks	5,266 06
Labor and teaming, removing earth from sidewalks	513 28
Lumber for sidewalks, crosswalks and general purposes	12,351 34
Crushed stone and gravel	69,525 99
Paving stone	1,783 00
Flag stone	674 05
Cedar blocks	5,688 35
Coal for steam roller	447 54
Ashing sidewalks and crosswalks	169 62
Hauling stone	1,877 49
Flushing asphalt pavement	1,887 36

If one expects to study asphalt, stone block, brick or cedar block pavements, there is perhaps no better place to go than to the city of Milwaukee. The pavements in this city have been constructed in various ways and in localities where they are

*From the Annual Report of the Department of Public Works.

subjected to very different traffic conditions. An examination of these pavements, with a knowledge of the manner in which they were constructed and of the atmospheric and traffic conditions to which they are subject, can teach one a great deal with regard to their respective merits.

The following are among the asphalt pavements which one should examine: 10th street from Grand avenue to Cedar, constructed in 1894; Grand avenue from 8th to 13th street, constructed in 1894; 12th street, between Grand avenue and Cedar; and 16th street, between Grand avenue and Clybourne.

Considerable improvement has been noted in the durability of the lately constructed asphalt pavements when compared with those built eight or ten years ago. The weak part of the asphalt pavement thus far has been the surface. That some parts of the asphalt pavement wear out faster than others may be attributed almost entirely to insufficient care in the construction of the pavement. It is exceedingly important that the ingredients should be properly mixed and that the mixture be applied to the surface at what has been shown to be the proper temperature for the composition used. The soft spots in an asphalt pavement may be due to a cooling of the mixture before it is spread over the surface. No person or company should undertake the construction of an asphalt pavement unless fully equipped with the necessary machinery.

Wherever this pavement has been laid on streets with car tracks it has been demonstrated that the ties should be laid in concrete, on a concrete foundation and that "toothing" stones should be laid on each side of the rail to protect the pavement. The toothing stones consist of a row of granite blocks or vitrified brick, laid as headers and stretchers on each side of the rails. Experience in Milwaukee has shown that the granite blocks are more desirable than brick and that the toothing stones should be laid on both sides of the rail.

It has been customary to extend the asphalt pavement up to the curbing without the construction of a special gutter. The stamping of the horses as they stand along the curb and the disintegration resulting from the accumulation of water render it


LAKE
SOUTH
PARK
LINCOLN
AVE
PARK
Stone Block Pavements.
Brick Pavements.
Macadam Pavements.
Cedar Block Pavements.
Gravel and Broken Stone.

Granite Block Pavement. Intersection of Second and Fowler Streets, Milwaukee, Wis.

Cedar Block Pavement. Wells Street, between Sixteenth and Eighteenth Streets, Milwaukee, Wis.

advisable to provide either concrete, stone or brick gutters. In Milwaukee three rows of Puritan paving blocks are laid between the asphalt and the curbing. The two inner rows are laid lengthwise of the street and the outer row is laid as headers and stretchers, after the manner of the toothing stones, next to the car tracks.

It has also been quite clearly demonstrated that the asphalt pavement is not adapted to heavy traffic streets. In several instances, asphalt has been laid on some of the heavy traffic streets, and in most instances the pavement has been badly rutted within a comparatively short time. Experiences of this kind have led the authorities to prohibit heavy teaming on boulevards which have been paved with asphalt. Asphalt pavements disintegrate if water is allowed to soak into them. For this reason the constant sprinkling of these pavements has been discontinued in Milwaukee. Instead of this, the asphalt pavement is washed once or twice a week with a hose from a hydrant and during each night the pavement is cleaned with scraper and brush. In this way the city has been able to appreciably increase the durability of the asphalt pavement, although the people are obliged to suffer more from fine dust and dirt than formerly.

The experience of Milwaukee with the cedar block pavement has extended over a considerable number of years and has included all known methods of using the cylindrical cedar block. The city engineer considers these pavements altogether unsatisfactory and is replacing them with a more permanent pavement as rapidly as the available funds will permit. Milwaukee has had no experience in the use of the modern creosoted, wooden block, such as is being used in St. Louis, Indianapolis and other cities.

It is thought that in the construction of many of the asphalt and brick pavements, a foundation of macadam could be used with perfect safety.

Milwaukee has three miles of brick pavement, the first of which was laid in 1895. These pavements all have six inch

concrete foundations and the brick are laid on a cushion of one to one and a half inches of sand.

During 1900 the city engineer was using brick instead of stone for paving the alleys.

Grand avenue, between 4th to 8th streets, was paved with brick in 1899. The brick shows some wear especially at the corners and along the edges. The street has worn very uniformly and although the "sets" are somewhat rounded at the surface the pavement may be said to be in good condition. The brick pavement on Mitchell street was laid in 1899. This pavement shows very little wear and is in excellent condition. The contrast between the cedar block and the brick on this street is very marked.

The only brick pavement which has been seriously injured by the traffic which it sustains is on Chestnut west of Third. Pabst brewery wagons, heavily laden with beer, pass over this street in going from the brewery to the depot warehouse. In less than two years this pavement has been almost entirely destroyed. Deep ruts were worn in the pavement in less than two years, some of the brick being reduced to one-half their normal thickness. In contrast with this pavement, one should examine the stone block approach to the brewery over which the same wagons are hauled. The driveway is paved with granite blocks which, although showing some wear, have deteriorated nowhere near as much as the brick pavement. The brick used in this street were tested in competition with other makes and in the laboratory withstood the highest test. It is thought that the brick used were as strong and durable as any of those tested; further, that no paving brick has yet been made which is equal in strength and durability to the best granite blocks manufactured in Wisconsin.

The experience of this city goes to show that granite and rhyolite are the only stone blocks which are giving satisfaction in Wisconsin. Limestone and dolomite blocks, manufactured at some of the Wisconsin quarries, have been used in Milwaukee to a greater or less extent, but they are not satisfactory. The purchase price of these blocks is less than that of granite and

Asphalt Pavement. Wisconsin Street, between Jackson and Van Buren Streets, Milwaukee, Wis.
Shows manner in which this pavement wears next to the rails.

Brick Pavement. Mason Street, between Broadway and Milwaukee Street, Milwaukee, Wis.

their durability is proportionately less. A good example of the manner in which the limestone block pavement wears can be seen on South Canal street, between 16th street and 1st avenue. This pavement was laid in 1896 and is subjected to heavy coal teaming. The surface of the pavement is very uneven, the ruts and ridges giving evidence of very rapid wear. The joints have become very wide and a considerable number of blocks have split lengthwise, showing that some of the blocks have been laid on edge. Certain depressions along the railroad tracks appear as though they have resulted from a settling of the foundation. Park street, from Reed to Clinton, was paved with limestone blocks in 1896 and is in very good condition today. The traffic on this street is much lighter than on South Canal.

A portion of Clinton street was paved with granite blocks in 1885-86-87. The pavement is in good condition today. The west side of the street shows more wear than the east which is probably due to the direction in which most of the heavy teaming is done. This difference in wear on the two sides of a street was frequently observed in this city. Reed street, above Lake and Park, shows the heaviest wear on the southwest side. Either the teams must be loaded going out and empty returning or else people drive on the southwest side during the summer to keep in the shade. St. Paul avenue, between 6th and 8th streets, is constructed out of Berlin rhyolite. The gutters along this street consist of four rows of granite blocks, laid lengthwise of the street. As the limestone curbing is approached, these blocks are gradually raised to carry the water into the gutter. In places this street is very rough, owing, in part at least, to the laying of service pipes. Apparently this pavement has been given very little attention in the way of cleaning or repairing.

The Board of Public Works of Milwaukee appreciates thoroughly the value of granite block pavement for heavy traffic streets. The principal objection to the granite block pavement has been its very rough surface. This is due entirely to the manner in which the blocks are prepared but under the pres-

ent specifications which require smooth heads and close joints this objection will be largely removed.

Milwaukee has had very little experience with macadam pavements. Most of the broken stone pavements have been looked upon as temporary improvements, and no careful supervision has been exercised in their construction. In most cases the broken stone pavements have consisted of a gravel foundation with a surface of crushed limestone. There are now about 234 miles of this kind of pavement in Milwaukee. Such a pavement, however, is not macadam and must not be confused with it.

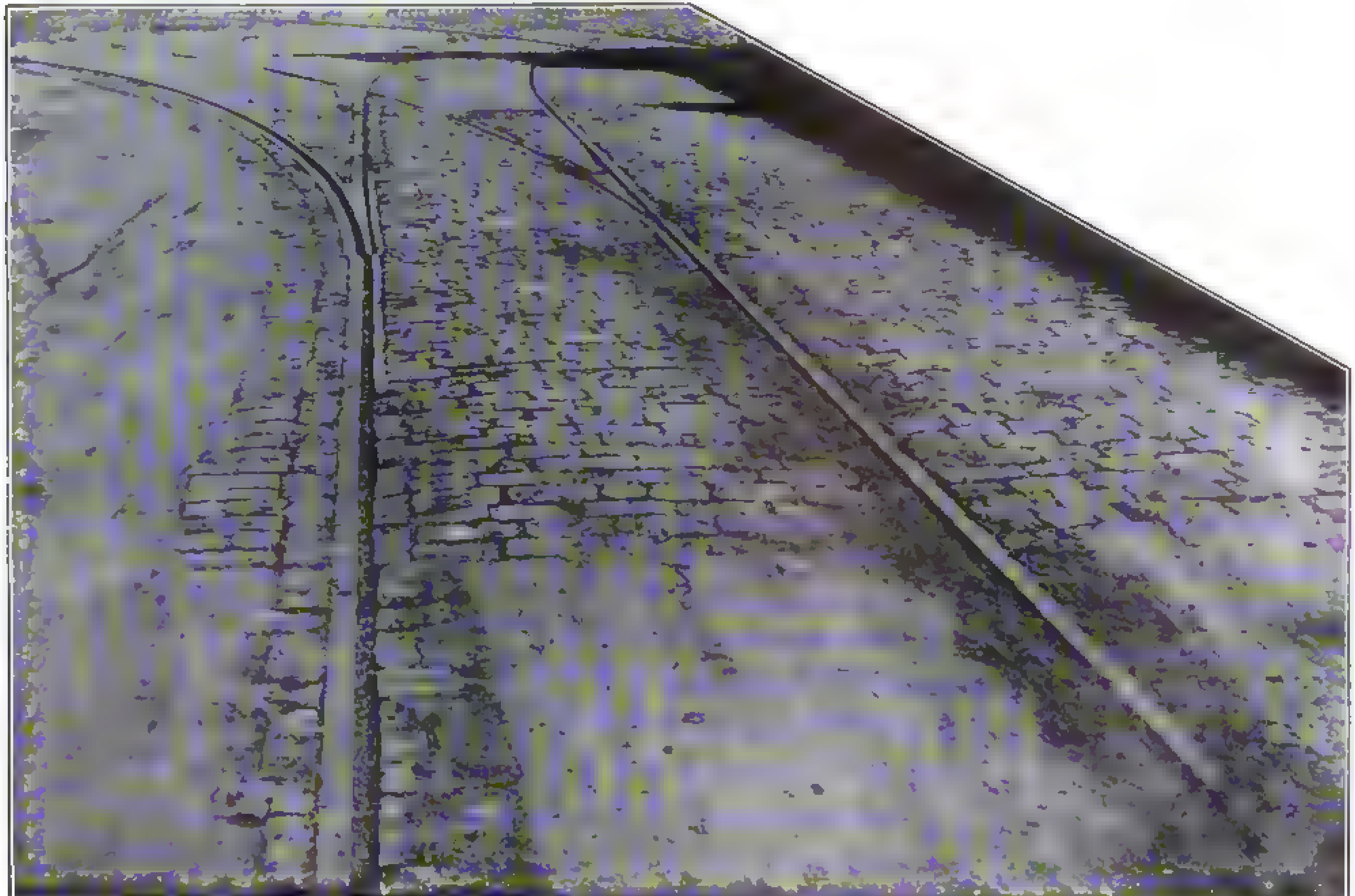
If a little more attention had been given to the construction of these pavements and a system of maintenance had been provided, many of these streets might have been in very good condition today. As it is, most of these streets have rough surfaces and are either muddy or dusty.

The city engineer reports among the paved streets .45 mile of telford macadam pavement. I believe that it is intended to extend the macadam pavements in the residence districts, using granite or trap rock for surfacing. One of the new limestone macadam pavements is on 14th street, north and south of Grand avenue. This street has been given a high crown and is in very good condition.

Milwaukee is not the best place to go if one wishes to investigate macadam pavements. Some of the smaller cities that have given more attention to this style of pavement can furnish more valuable information.

Milwaukee has not yet indulged in the construction of asphalt block, asphalt rock, modern wooden block, granolithic or any of the other numerous pavements which are being tried in various parts of the country.

Before closing this discussion on the Milwaukee pavements, the reader's attention is called to the following reference to sidewalks which is quoted from the city engineer's report for 1900. He says: "The plank walks have been very expensive to the city, in the way of damages from accidents, and in my opinion the time will soon arrive when no more plank walks



Asphalt Pavement. Intersection of East Water and Oneida Streets, Milwaukee, Wis.
Showing use of granite blocks between the street car tracks.

Granite Block Pavement. Entrance to Pabst brewery. Heavy traffic.
Compare with pavement illustrated on opposite page.

should be laid upon the public streets." The construction of permanent sidewalks, crosswalks, culverts and other miscellaneous street constructions is fast taking hold of the city of Milwaukee. In this respect she furnishes an example which should be followed by all of the smaller towns, cities and villages of the state.

NORTH MILWAUKEE.

(Pop., 1,049.)

The village of North Milwaukee is located in Milwaukee county near the city of Milwaukee. This village has macadamized nineteen blocks of streets. The first macadam was laid on Green street in 1899. One block on this street was improved. In the spring of 1900, three blocks of Western avenue, between Green street and Villard avenue, were macadamized. In the fall of 1900 and in the spring of 1901, Villard avenue, between the Cedarburg and Hopkins roads, eleven blocks, was macadamized. In the fall of 1901, four blocks of Western avenue, between Villard avenue and Boise avenue, were macadamized. Limestone was used for building the pavements and also for curbing which was set next to the sidewalk. No special gutters of flagstone, cement concrete or brick have been constructed.

The streets are from 34 to 42 feet wide and the pavements are given a crown of from two to eighteen inches. The macadam consists of a foundation of three inch flagstone upon which is spread from twelve to sixteen inches of crushed stone.

The curbing may be either wood, stone or cement, the choice being left to the pleasure of the property owners. No special gutters are provided either to carry off the storm water or to protect the pavement.

SOUTH MILWAUKEE.

(Pop., 3,392.)

The streets of South Milwaukee are all comparatively new. The subsoil is mainly clay and the improvements have been confined to grading and graveling. In 1899 the condition of the streets was reported to be far from satisfactory.

WAUWATOSA.

(Pop., 2,842.)

This city was incorporated in 1898 and prior to that time no records were kept of the street improvements. The accompanying statistical table shows the streets which have been improved since that time and the cost of such improvements.

Crushed limestone and gravel are the materials used in making the improvements.

The substitution of granite or trap rock for limestone as top dressing and the giving of careful attention to the maintenance of the pavement should place the streets in good condition.

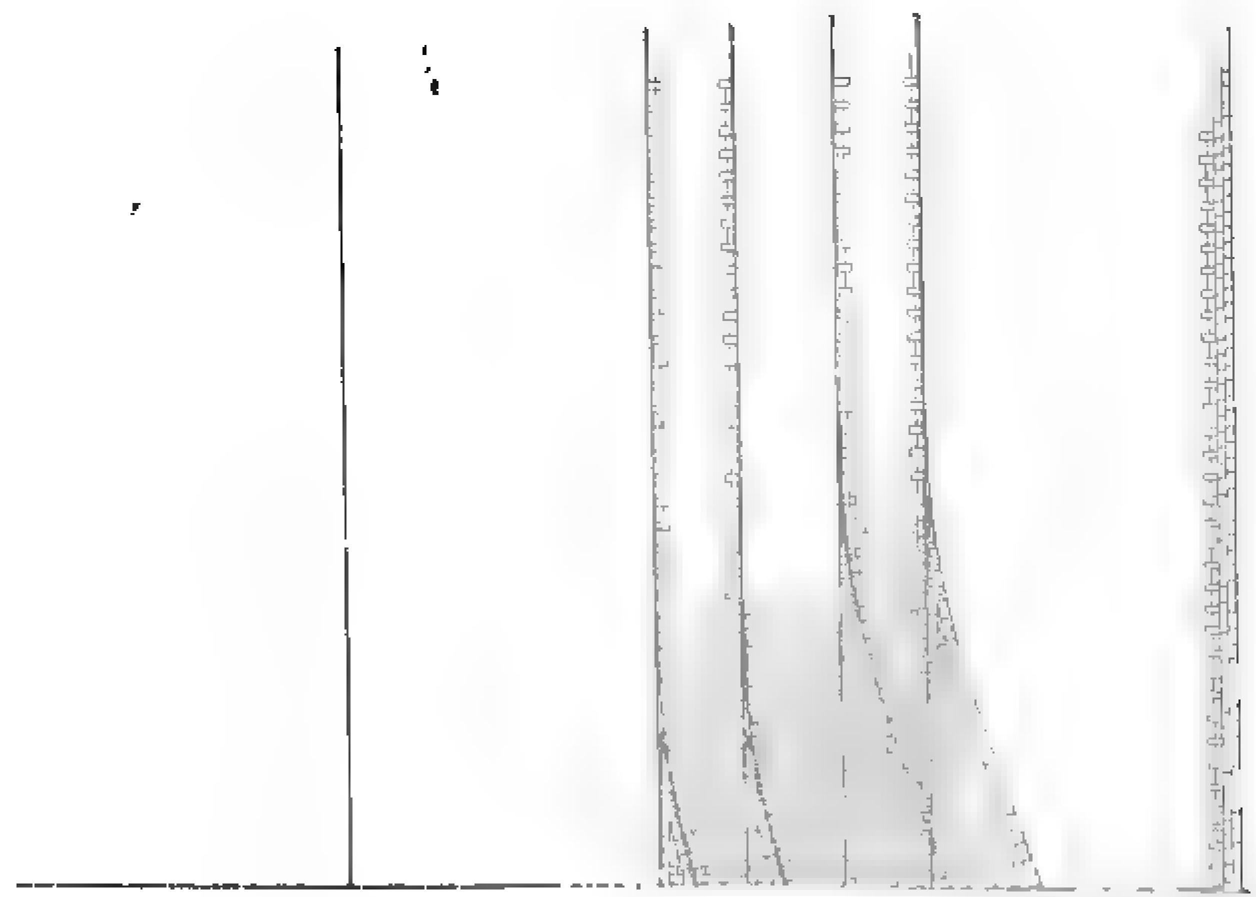
MONROE COUNTY.

Monroe county is located in the west central part of the state. The northern part of the county contains extensive tracts of marsh land separated by low hills and ridges. The southern half of the county is rough and hilly, the topography being characteristic of the stream erosion of the driftless area in which the county is located.

The soils in the northern two-thirds of this county are mainly sand and sandy loams, through which occur occasional irregular areas of humus soils composed mainly of muck and peat. The soil in the southern one-third of the county is mainly clayey loam of a light and medium variety. Being entirely within the driftless area the county contains no boulders of granitic or other igneous rocks. The tops of the ridges are strewn with irregular boulders of flint which are residual after the decomposition of the limestone. Banks of flinty gravel occur along many of the stream channels especially in the southern half of the county. These gravels are now used to some extent for improving the rural highways.

The country is largely underlain with sandstone of the Potsdam formation. The ridges and hills in the southern half of the county are capped with Lower Magnesian limestone. This limestone really constitutes the chief supply of available stone for road metal. It is thought that if this limestone were used in conjunction with the flint gravel a very good pavement might

Vitrified Brick Pavement. Chestnut Street, between Fifth and Seventh Street, Milwaukee, Wis. Heavy traffic.
Two years old when photographed.



Street Car Track Curves, Milwaukee, Wis.

Wauwatosa.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction. Foundation. Kind.	Foundation. Thickness.	Surface. Kind	Surface. Thickness	Where material was obtained.	Average width of street between curbs	Cost of construction per sq. yd., exclusive of curb, gutter and underground pipes.
E. Milwaukee Ave....	....	Aug., 1900	Clay........	.. ..	Crushed limestone.	10 in.	Local quarry .	32 ft.	$0.70
First Ave.............	....	Sept., 1900	Clay	......	Gravel	16 in	Local gravel bank.	30 ft	0.525

Sparta.

Name of street.	Part paved, macadamized, etc.	Date.	Foundation. Kind.	Foundation. Thickness.	Surface. Kind	Surface. Thickness	Where material was obtained.	Average width of street between curbs	Cost of construction per sq. yd.
Water....	From Oak to Fr'nkl'n	1896	Plank (2) ..	3 in.	Tarred cedar block.	8 in.	....	32 ft.	$3 40
Oak	From Court to Bent'n	1896	Flagstones and sand.	3 in.	Gravel and limestone.	12 at center 8 at curb.	Sandstone from Sparta, limestone from Winona.	36 ft.	$1.20 inc. curb and gutter.

be constructed. Shaly beds of sandstone occur in some parts of the county and these may be used to advantage for temporary road improvements.

SPARTA.

(Pop., 3,555.)

Up to the 1st of January, 1901, Sparta had three blocks of cedar block pavement and three blocks of limestone macadam.

The foundation of the macadam on Oak street consists of flag stone about four inches thick covered with sand. The wearing surface consists of about twelve inches of crushed limestone spread in two courses. The thickness of the crushed stone at the curbing is eight inches. Each course was well watered and rolled and the surface was covered with $1\frac{1}{2}$ inches of bank gravel. Including the curb and gutter, the pavement cost $1.20 per square yard. The macadam was constructed unnecessarily thick which accounts in part for the seemingly high price.

The subsoil in this vicinity is mainly sand. In a few places where sloughs and old stream channels have been filled, the subsoil is soft and mucky.

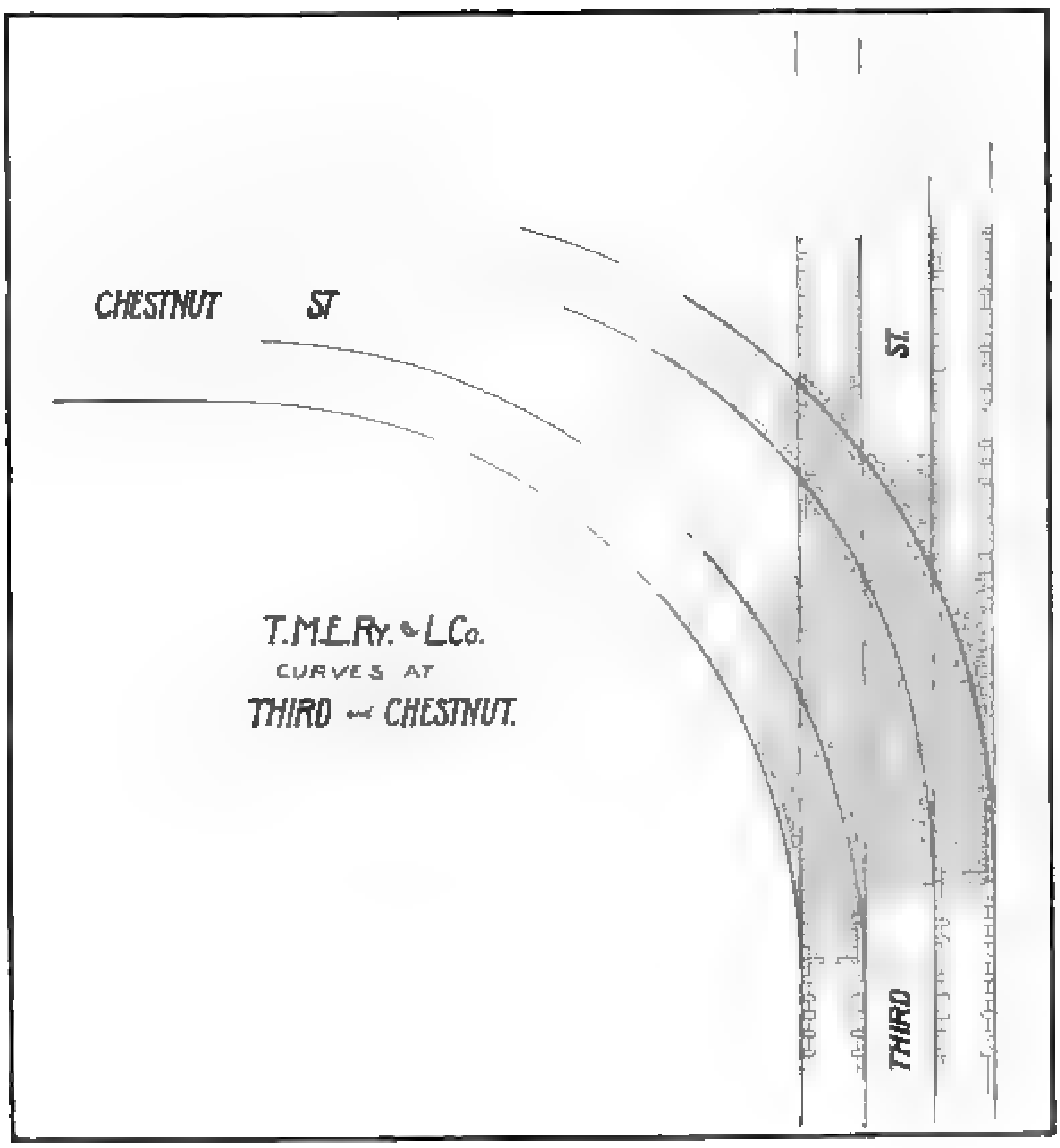
During the past summer, 1901, the city has been constructing additional macadam pavements using limestone for the foundation and quartzite for the wearing surface. Where macadam pavements are built with a limestone foundation and a surfacing of granite or quartzite, a greater thickness than seven or eight inches is unnecessary.

In this region there is no granite or trap rock and the limestone is of poor quality. Most of the stone must be shipped in, which makes the macadam pavement more costly than it should be. Flint gravel is found in some places near the city and it is thought that this might be used, in part at least, for the foundation course.

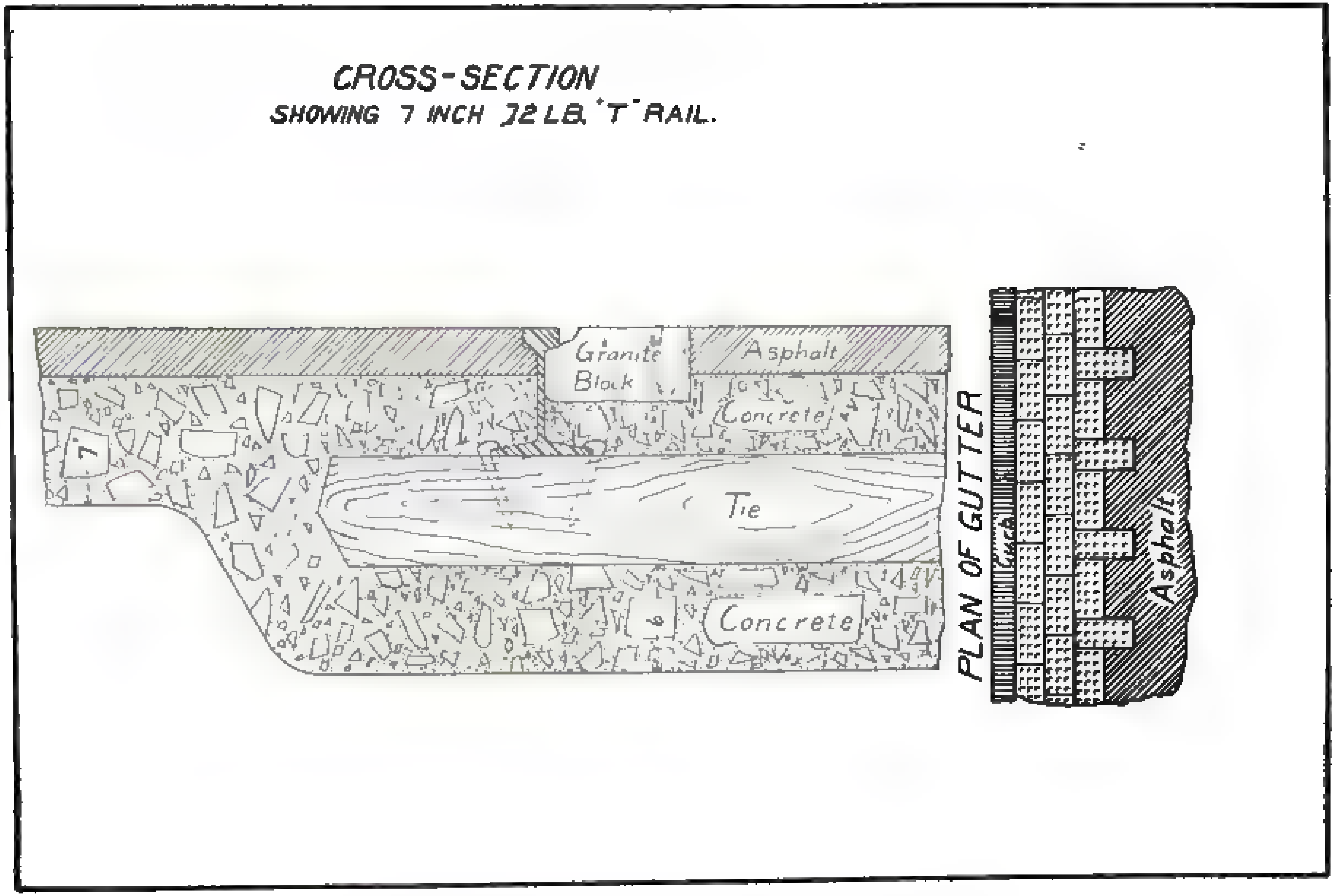
TOMAH.

(Pop., 2,840.)

None of the streets of this city have been paved or graveled. The subsoil on most of the streets is sand. The surface water is removed by means of gutters and underground tiling.



Street Car Tracks. Intersection Third and Chestnut Streets, Milwaukee, Wis.



Cross Section Asphalt Pavement. Showing T Rail, Milwaukee, Wis

OCONTO COUNTY.

Oconto county is located in the northeastern part of the state on Green bay. With the exception of an area adjacent to Green bay, the county is generally rough and hilly, especially in the northern part. The topography has been modified by glacial erosion and decomposition and subsequently by stream erosion. The soils are very largely clayey loams. A strip of sand and sandy loam about eight miles wide extends through the county from southwest to northeast. There are several irregular areas of sand and sandy loams in the southeastern part of the county in the vicinity of Green bay. Numerous irregular areas of humus soils, composed mostly of muck and peat, occur in different parts of the county.

As indicated above, the surface of the county has been modified by glacial erosion and deposition. Fragments of granitic, gneissoid and trap rocks have been strewn, by this agent, over nearly all parts of the county. This field stone should eventually constitute an important source of supply for road material.

The northern part of the county is underlain with igneous, gneissoid and trap rocks which outcrop in numerous places throughout that section of the country. South of this pre-Cambrian area, occurs a belt of Potsdam sandstone; a belt of Lower Magnesian limestone; a thin strip of St. Peters sandstone; a narrow belt of Trenton limestone; and one of Galena limestone, which borders on Green bay. The Trenton and Galena limestones can be used to advantage in the foundations for broken stone pavements. The granitic and trap rocks ought, however, to be used altogether for surfacing.

For the temporary improvement of many of the highways the gravel, which occurs in various parts of the county and especially along the stream channels, can be used to advantage.

OCONTO.

Pop., 5,646.)

Up to 1899, the only improvements to the streets of Oconto were made by covering the subsoil with gravel and shavings.

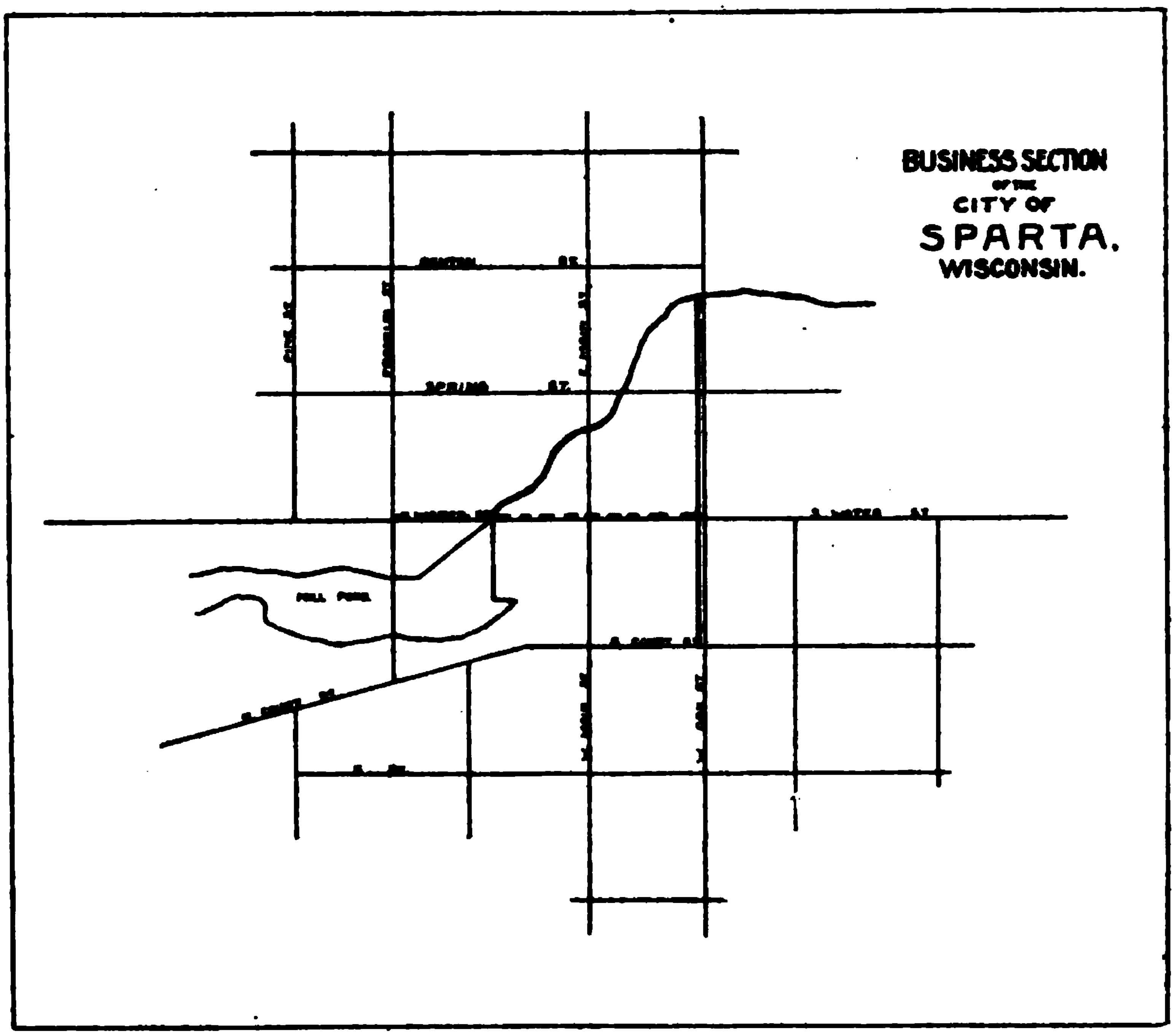
The natural subsoil in this vicinity is sand, gravel and clay loam, but saw-dust, shavings and slabs have been added for so many years that it is now necessary to excavate and remove the subsoil to a considerable depth before the pavement can be safely constructed. Main street, which is the business thoroughfare, is the only street that has been macadamized. Field stone, of the granite and trap rock varieties, was used for this purpose. The city owns a crusher and when Main street was macadamized an 18 ton roller was obtained from Green Bay.

The sidewalks are mainly wood, cement having been used only on Main street. The city does not regulate the construction of sidewalks except in establishing the grade, position and width of the walk.

Mr. W. B. Hall, to whom I am indebted for this information, says that up to the present date about 14¾ miles of streets have been graveled. He also observes that these streets will not wear over six months without the necessity of repair; that as a whole, the streets are in bad condition, being very poor in wet weather; and that the experience of Oconto goes to show that the gravel is undesirable for heavy traffic unless well crowned and drained, and that in very wet weather such streets are almost impassable.

For the information of anyone who may inspect the streets in this city, it may be well to say that the foundation of the graveled streets consists of from one to six feet of saw-dust and shavings and that the gravel surfacing has a thickness of only about eight inches.

Streets, that are improved as Main street, must be classified among the partly finished streets. In addition to the bare pavement, a street should have underground drains, gutters, sometimes curbing, and brick, stone or cement sidewalks and crosswalks. If a park area is left between the curb and the sidewalk, it should be graded, sodded and planted with shade trees.



Macadam Pavements.

Cedar Block Pavements.

ONEIDA COUNTY.

Oneida county is located in the north central part of the state. The surface has been shaped very largely by glacial erosion and deposition. The northern part of the county has a pitted surface due to the irregular manner in which the glacial drift is distributed. The county is underlain with granitic and other igneous rocks which outcrop mainly along the stream channels. Very few outcrops occur in the northern part except where occasional hills or ridges rise above the general level of the county.

The gravel an boulders which are strewn in large quantities over the land should constitute by far the most important source of materials for road metal. The gravel should not be used alone except for temporary improvements. The small boulders should be collected in piles and crushed, permanent broken stone pavements being constructed therefrom.

OUTAGAMIE COUNTY.

Outagamie county is located in the northeastern part of the state directly north of Lake Winnebago. The surface of the county is rolling except along the stream channels and tributaries which break the land into ridges, hills and valleys. The county lies within the glaciated region and the surface has been modified by glacial erosion and deposition. Two-thirds of the county is covered with clayey loams derived from the red lacustrine clays. The northwestern part of the county is underlain largely with a light clayey loam through which occur occasional small areas of sand. Irregular areas of humus soils, composed of muck and peat, occur throughout the county.

The formations underlying this county are mainly limestone of the Galena, Trenton and Lower Magnesian formations which occupy the southeastern two-thirds of the county. The northeastern one-third of the county is underlain with Potsdam sandstone. A thin irregular strip of St. Peters sandstone traverses

the county from north to south between the Lower Magnesian and Trenton limestone areas.

The chief sources of road metal for this county are found in the Galena, Trenton and Lower Magnesian limestones and the glacial boulders which constitute the field stone in different parts of the county. Directly southwest of New London, a distance of about three or four miles, in Waupaca county, occurs a hill of fine grained granite. This granite might be used to advantage in providing road metal for the highways in the southwestern part of the county. The following description of the pavements in Appleton, Kaukauna and New London will give an idea of the character of the improvements now being carried on.

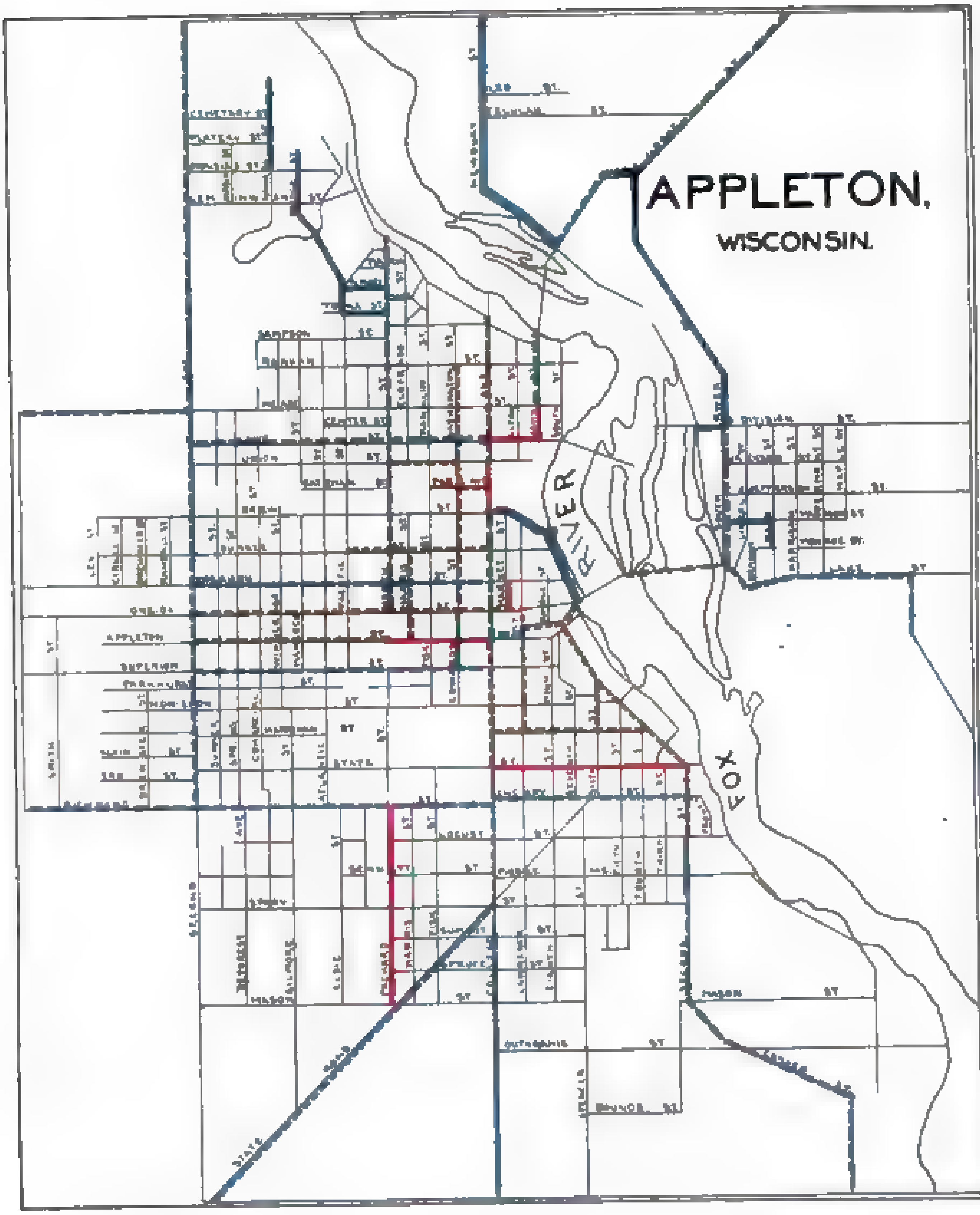
APPLETON.

(Pop., 15,085.)

Up to January 1st, 1901, Appleton had 5½ miles of cedar block pavements, 3½ miles of limestone macadam and 12½ miles of graveled streets. Gravel was first used in 1868, macadam in 1883 and cedar blocks in 1890. The experience which Appleton has had with cedar block pavement is the same as that of other Wisconsin cities. The cedar block pavements have been without exception unsatisfactory and the city engineer reports that they have only worn on an average of eight years before it became necessary to make repairs.

The subsoil in this city is either a plastic red clay or sawdust, which, as a rule, provide very unsatisfactory foundations upon which to construct pavements. An example of the ordinary clay subsoil of this city may be seen on 2d avenue, between Richmond and North Division streets. This street is turnpiked but during wet weather is in very bad condition, being at times almost impassable.

The clay streets which resembled 2d avenue were improved at an early day by spreading gravel over their surfaces. The gravel was obtained close at hand and has improved very greatly the condition of the roadways and has also made a safer subsoil on which to build pavements. Gravel is at present used on



Cedar Block Pavements.

Gravel

Macadam Pavements.

Cinders.

some of the streets. North street, from River to Oneida, may be pointed out as an example of a good gravel street. The street is narrow, has a high crown and is well drained. The width of this roadway is sufficient to accommodate the traffic and in constructing macadam pavements it would be economy to take some ideas regarding the necessary width of the pavement from this street. Richmond street has also been improved with gravel. It had originally a very high crown and today is in very fair condition, although a few low places permit the accumulation of pools of water. Apparently the traffic has flattened the crown to the street and it is now almost flat on the top. The flattening of the crown in this manner causes the retention of rain water which should otherwise flow into the gutters. College avenue, from Drew to Appleton streets, is in very good condition, having been improved with a dressing of fine limestone screenings.

Macadam pavements have been constructed on John and Lawe streets; on College avenue between Union and Drew streets; one block on Park avenue next to the Park; and on La Salle street from College avenue to 2nd street. No special gutters have been constructed, although limestone curb has been used. The crown is low but sufficiently high to carry off the water.

College avenue, between State and Cherry streets, has been improved with cinders. It is reported that this street is in bad condition in the spring when the frost goes out of the ground. The limestone macadam pavements are the best which have thus far been constructed in Appleton. The method of construction has differed somewhat for different streets. Some have a very high and others a very low crown; some streets are broad, while others are narrow; on some the crushed stone is thick and on others it is thin. Very little attention has been paid to the construction of adequate gutters for carrying off the surface water, although limestone curbing has been set up on most of the streets. The single block of macadam on John street and the two blocks on Lawe street have been improved with the combined cement curb and gutter. However, the gutters which have been constructed are too narrow to accommo-

date the water which they may be called upon at times to carry off.

The tendency to drive single horse vehicles in the center of the street on either side of the car tracks is especially noticeable on State street, between College avenue and 2nd street, where ruts are already being formed in the pavement.

The expense of keeping up the limestone macadam is much greater than keeping up the granite macadam, and on this account, the city should provide that all macadam pavements hereafter constructed shall have at least a top dressing of granite or trap rock. Granite for the surface and local limestone for the foundation will make an excellent combination pavement for the residence streets. The cost of maintenance will be less and there will be less dust and mud during the summer months. At present this city has no adequate system of maintenance and unless this is provided, to keep up the macadam, it is to be feared that this pavement will soon be in disfavor. A macadam pavement to be satisfactory must be kept in repair.

KAUKAUNA.

(Pop., 5,115.)

The only street pavements in Kaukauna (north side) are limestone macadam which were built in 1888 and 1892. In the former year Wisconsin avenue was macadamized from the Union Paper Mills to DesNoyer street. From DesNoyer street to the depot, Wisconsin avenue has been partially improved by the addition of broken stone. That portion of the pavement between the Paper Mill and DesNoyer street has a very flat crown. The shallow depressions on the surface sometimes collect and retain the surface water. The subsoil in this vicinity is a red plastic clay, which constitutes a poor foundation for any pavement.

The macadam on Wisconsin avenue has a thickness of about 2½ feet. Large stones were laid on the bottom and the size was gradually decreased until the surface was reached. This pavement cost about $10,000. In 1892, Main avenue from the

river to a place about one block north of Wisconsin avenue was macadamized.

On the south side of the city, 2nd street has been macadamized between Dodge and Reaume avenue; 3rd street between Crooks and Reaume avenue; Main avenue from the railroad tracks to 3rd street; and Crooks avenue, from 2nd street to 3rd street. The macadam pavements on this side of the city are built with a high crown, being rather flat on the top and steep next to the gutters.

The pavements have not been constructed in the best possible manner, but they are, nevertheless, a vast improvement over the sticky red clay which covers many of the streets that have not been paved. In some places the broken stone has been spread over a greater width of the street than is necessary. There is no uniformity in the kind of curbing used and very little attention has been paid to the construction of gutters.

The city owns a crusher and there is an abundance of limestone already quarried along the government locks. This limestone is from the blue beds of the Trenton formation and is considered one of the best limestones for macadam purposes which is found in the state.

None of the pavements have been repaired since they were constructed and, taking this fact into consideration, we may truly say that they are in remarkably good condition.

NEW LONDON.

(Pop., 2,742.)

Prior to 1898, the streets of New London were improved entirely by grading and graveling. In 1898, the city bought a crusher and began constructing macadam pavements. Hard heads, (granite and trap rock boulders), of such size as could be readily handled in the crusher, were purchased from the farmers. Up to 1900 the city had macadmized about three-fourths of a mile of the main street, which is subject to the heaviest traffic in the city. Very little money has been spent in

maintaining or repairing this street, and when examined during the fall of 1900, it was in excellent condition.

There is an abundance of field stone of the granite and trap rock varieties near this city. A short distance south of the city occurs an outcrop of fine grained granite, resembling that which is quarried at Montello. This is an excellent stone for macadam purposes and could be quarried and crushed with comparative ease.

SEYMOUR.

(Pop., 1,026.)

The city owns a crusher and for three years has been building limestone macadam pavements. The pavement has been constructed the entire width of the street. No curbing has been used and the surface water has been carried away by gutters built out of the crushed stone used for the macadam pavements.

The soil in this vicinity is a loam. The streets are cleaned by using a modern wood scraper, by which the refuse is collected in piles and then hauled away by teams.

Mr. F. L. Forward, mayor of the city, to whom I am indebted for this information, says that he expects by the time all the streets have been paved, they will need to commence where they started and make repairs. However, with cheap rock near at hand, the cost of repairs ought not to be very great.

OZAUKEE COUNTY.

Ozaukee county is located in the southeastern part of the state on Lake Michigan. The surface is rolling and somewhat hilly, especially in the western part. The surface has been modified by glacial erosion and deposition and also by river erosion. The soils are mainly clayey loams of the heavier varieties. Those in the eastern part have been derived from the red lacustrine clays. A small strip of land in the northeastern part, along Lake Michigan, is covered with a sandy loam. The western part contains numerous hills composed mainly of boulder clay and limestone gravel. The surface of this portion of the county

is also strewn with boulders of granitic and other igneous rocks. The underlying rock is entirely limestone, mainly of the Niagara formation.

The principal sources of road metal are the quarries in the Niagara limestone and the field stone, which forms a part of the glacial drift.

PORT WASHINGTON.

(Pop., 3,010.)

The streets of Port Washington have been improved entirely by grading and the addition of gravel and crushed stone. In 1894 sixty-six feet of street crossings were laid with cedar blocks. These are reported to be in good condition today. In 1897 a number of crossings were constructed out of limestone blocks and these are also in good condition.

About two miles of combination crushed stone and gravel pavements have been constructed during the last four years. The streets which have been thus improved are repaired each year, at a cost of about $450 per mile. Besides this it costs $75.00 per mile a year for cleaning. The main objection to these pavements is their uneven wear, which results in irregular rolling surfaces.

The following is a list of the principal streets that have been improved up to January, 1901.

Port Washington.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction.				Where material was obtained.	Average width of street between curbs.	Total cost of construction.
			Foundation.		*Surface.*				
			Kind.	Thickness.	Kind.	Thickness.			
Grand avenue	All paved	1897	Gravel and crushed stone	Av. 1 ft.	Fine gravel	10 to 12 in.	Local quarry	50 ft.	$5,500 00
Wisconsin	All paved	1897	do	do	do	do	do	do	
Washington	All paved	1898	do	do	do	do	do	do	
Pierce	All paved	1897	do	do	do	do	do	do	
Franklin	All paved	1897	do	do	do	do	do	do	
Main	All paved	1897	do	do	do	do	do	do	
Chestnut	All paved	1897	do	do	do	do	do	do	

None of the pavements on these streets can be considered permanent. The streets are variously graded and crowned and are covered with an irregular thickness of crushed rock and gravel. Very little attention has been paid to constructing suitable gutters and no attempt has been made to park the streets. The use of crushed granite and trap rock boulders for top dressing would increase very materially the durability of the pavements. More attention should be paid to keeping the pavements in such a condition that extensive repairing will be unnecessary.

PEPIN COUNTY.

Pepin county is located in the west central part of the state on the Mississippi river. The western part of the county, adjacent to the Mississippi and Chippewa rivers, is very hilly. The eastern part is not as rough as the western but is still of a rugged character.

The soils in the western part of the county are mainly clayey loams, while those in the eastern part are mainly sandy loams. The soils along the Mississippi and Chippewa rivers are mainly sand.

The glacial drift in this county is very light and in consequence the supply of field stone and gravel is not as abundant as in the counties which are heavily covered with drift.

This county is very largely underlain with Potsdam sandstone. In the western and southern sections the tops of the ridges and hills are capped with Lower Magnesian limestone.

The gravel which is occasionally found along the streams and the limestones from the tops of these ridges constitute the most abundant sources of stone for road metal.

PIERCE COUNTY.

Pierce county is located in the west central part of the state on the Mississippi river. This county is rolling and hilly in nearly all of its parts. Along the Mississippi river the bluffs are steep, although the tops of the ridges are level or rolling.

The soils in this county are almost entirely clayey loams of either the lighter or heavier varieties. In the southern part of the county, along the river, the soils are sandy. This county is in the region covered by the earlier glacial deposits but the present topography is largely a result of stream erosion. A greater part of the county is underlain with Lower Magnesian limestone, although the more elevated ridges and table lands in the central and northern sections are capped with Trenton limestone. Between the Trenton and Lower Magnesian limestones occurs an intermediate area of St. Peters sandstone.

The blue beds of the Trenton limestone and the hard finely crystalline beds of Lower Magnesian limestone offer the best material for the improvement of the highways. The extent of the glacial deposits, including foreign boulders and gravel, is not known. This county, in conjunction with most of the others, should be carefully examined to ascertain the location and distribution of the best stone available for improving the highways.

POLK COUNTY.

Polk county is located in the northwestern part of the state on the St. Croix river. The surface relief of this county has been largely modified by the erosion and deposition of the glaciers. The county is traversed by a range of hills, having a northeast-southwest trend, which are composed of diorite, diabase, melaphyre and other varieties of so called trap rock belonging to the Keweenawan formation.

The soils in this county are mainly light clayey loams. In the western part there is an area of heavy clayey loam, while in the northwest and south central portions occur areas of sand and sandy loams.

This county contains large quantities of glacial and stream gravel, as well as field stone. Trap rock outcrops in many places throughout the county, constituting an inexhaustible supply of the best kind of stone for road metal. Between Osceola and St. Croix Falls there are unlimited quantities of trap rock, near the railroad, which present exceptional opportunities for

the location of crushing plants. This county and many of those to the south ought eventually to be supplied with road metal from this region.

PORTAGE COUNTY.

Portage county is located in the central part of the state. The topography is diversified, some portions being level and others rolling and hilly. With the exception of small areas in the northeastern and northwestern portions of the county, the soils are entirely sand or sandy loam. Large irregular areas of humus soils, consisting mainly of muck and peat, are found in different parts of the county. The surface of the county has been modified by glacial erosion and deposition. The terminal moraine of the last glacial epoch passes through the eastern part, giving to the surface the irregular pitted topography so characteristic of such deposits. The ridges and hills in this part of the state are composed mainly of boulder clay, gravel and sand. The gravel is mainly limestone while the larger boulders are granite, porphyry and trap rock. The glacial deposits in this county furnish an excellent source of materials for road improvement.

The underlying rock in the southeastern two-thirds is sandstone. That in the northwestern portion is granitic and gneissoid rock belonging to the pre-Cambrian formations.

With the glacial deposits in the eastern part and the granitic and gneissoid rock outcropping in the northwestern part, the county is well supplied with excellent stone for road metal.

STEVENS POINT.

(Pop., 9,524.)

Up to January 1, 1901, Stevens Point had one mile of cedar block pavement and 2½ miles of granite and quartzite macadam. The following table contains a list of the paved streets, and other miscellaneous information relative to the materials used, cost of construction, etc.

Stevens Point.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction.				Where material was obtained.	Average width of street between curbs.	Cost of construction per sq. yd., exclusive of curb, gutter and underground pipes.
			Foundation.		*Surface.*				
			Kind.	Thickness.	Kind.	Thickness.			
Stronge Ave...	¾ mile.	1896	Granite and sandstone.	6 in.	Fine crushed granite.	3 in.	Twp. No. 24 R. 8 E.	32 ft.	$0.40 per sq. yd.
Main street....	¼ mile.	1896	...... do	6 in.	..... do	2 in.	...... do	30 ft.	.35 per sq. yd.
Division street	¾ mile.	1897	...... do .. .	8 in	. .. do	2 in.	...... do	30 ft.	.40 per sq. yd.
Clark street...	¾ mile.	1898-9	...... do	8 in.	..... do	2 in.	.. . . do	30 ft.	.25 per sq. yd.
Church street.	From Wis. Cent. Ry., to City Limits.	1900	..... do	6 in.	...... do ...	2 in.	.. . . do	16 ft.	.25 per sq. yd.

In commenting upon the character of the pavements used in this city, Mr. T. J. Murray, the city engineer, says, "Our experience with cedar block pavements has not been very extensive, but we have found by experience that macadam is the correct pavement for our city. It is easy to repair and is not noisy or dusty, if kept sprinkled for the first year. After the fourth year, cedar block pavements are just like corduroy for driving over. We had some blocks that rotted in three years and if we were to remove any blocks from our first pavement, constructed nine years ago, they would fall to pieces. It is fair to say that the life of cedar block in this locality, if kept well repaired, is about 12 years, the last three being a poor rough street."

Stevens Point constructed the first cedar block pavement in 1890 and continued adding a few blocks each year until 1894. In 1896 the city bought a crushing plant and roller and built the pavement on Strong's avenue as an experiment. This pavement was entirely satisfactory and other streets have been macadamized each year up to the present time. The stone used in these pavements is granite, which costs the city about $2.50 per cord. The cost of the finished pavement is about 35c. per square yard. Mr. Murray says, "The only mistake we have ever made was in the crown. We now give 7-10 and that is all O. K. Macadam streets naturally wear more on the crown than any other part. The moving vehicles pulverize the stone and rain and sprinkling washes it away. The street naturally gets lower in the middle by use. We use eight inches of macadam in the center of the street and six inches at the curb. The surface is dressed with two inches of very fine screenings."

The experience of Stevens Point is only that of a great many other cities in the use of granite and trap rock for macadam. It proves almost universally satisfactory for residence streets. With broad gutters to carry off the storm water and to withstand the stamping of the horses next to the curb and a systematic method of maintenance, the macadam pavement ought to give good satisfaction. On the business streets it is thought that brick as a whole would be more desirable.

PRICE COUNTY.

Price county is located in the north central part of the state. Except in close proximity to the stream channels, the surface is rolling rather than hilly. Irregular mounds and ridges occur in various parts of the county, as the result of glacial deposition. The soils in a large part of the county are light clayey loams. An area of sandy loam occurs in the eastern part and another in the northwestern part. Numerous irregular areas of humus soil, composed mainly of muck and peat, occur in various sections of the county.

The underlying rocks are mainly of the granitic and gneissoid varieties, belonging to the pre-Cambrian formations. The gravel along the streams is all composed of granitic and gneissoid fragments, as is also the gravel in the hills resulting from glacial deposition.

The gravel and boulders strewn over the surface and the underlying granitic and gneissoid rocks furnish an unlimited supply of stone for road metal.

PHILLIPS.

(Pop., 1,820.)

None of the streets of this village have thus far been improved in any other way than grading. No curbing or special gutters have been provided to remove the surface water.

RACINE COUNTY.

Racine county is located in the southeastern part of the state on Lake Michigan. The soils in this county are mainly light and medium varieties of clayey and prairie loams. The only considerable area of sandy soil occurs in the eastern part of the county along Lake Michigan. Irregular areas of humus soils are found in different parts. In the western part occur hills and ridges comprising a part of one of the terminal moraines. The eastern part of the county is underlain by lacus-

Macadam Pavements.
Limestone Block Pavements.
Cedar Block Pavements.
Brick Pavements.

trine clays, giving a rolling rather than a hilly topography to the surface to the land.

The underlying rocks are entirely Niagara limestone. This stone is quarried at a number of places and is crushed and used very extensively for street paving and concrete work. It is thought that a generous use of the field stone occurring in the western part, combined with the limestone, would provide excellent road metal. There are considerable quantities of gravel in the county but for any but temporary improvements, it is not satisfactory.

RACINE.

(Pop., 29,102.)

Up to January 1, 1900, Racine had .91 of a mile of limestone block pavement, 1.49 miles of brick and 4.65 miles of cedar block,—a total of 6.05 miles of pavements. During 1900, 6th street, between Main street and Lake avenue, was paved with cedar blocks, the last of its kind in Wisconsin. In 1901, the city began the construction of macadam pavements in the residence districts. Some of this work is shown in the accompanying illustrations.

The following is a list of the streets paved up to January 1st, 1901, together with those for which plans and specifications have been prepared.

Racine.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction. — *Foundation.* Kind.	*Foundation.* Thickness.	*Surface.* Kind.	*Surface.* Thickness.	Average width of street between curbs.	Cost of construction per sq. yd. exclusive of curb, gutter and underground pipes.	Cost per lineal foot of curbing.	Total cost of construction.
Alley block 13	From 3rd to 4th	1899	Macadam	6 in.	Brick		14 ft.			$1,120 80
6th	From Main to Lake avenue.	1900	Sand		Cedar blocks.	6 in.	40 ft.			
6th	From Main to Park avenue.	1884			Limestone block.					5,053 00
Main	From 3rd to 5th	1884			do					7,907 64
6th	From W. L. Mon. Sq. to Main.	1889			do					
W. S. of Mon. Sq.	From 5th to 6th	1889			do				.65	9,276 31
5th	From W. L. Mon. Sq. to Main.	1889			do			$1.40		
Main	From S. Line 6th to N. Line 5th.	1889			do					
4th	From W. Line Main to E. Line Wis.	1889			do				.65	1,636 60
Main	From N. Line 3rd to C., M. & St. P. tracks	1889			do				.65	6,380 74
E. State	From Main to State street viaduct.	1891			do			1.98	.64	2,693 88
6th	From Park Ave., to W. L. Grand Ave.	1891						1.80	.69	5,909 76
State	From Root river to C. & N. W. Ry.	1891			Cedar block			1.17	.60	22,575 78
St. Clair	From State to Duck Creek.	1892			do			1.09	.69	3,783 13
Washington Ave., and other Sts.	From 6th to S. Line 14th.	[illegible]			do			1.15 / 1.10	.63	26,712 42
Center	From 6th to Washington Ave.	1892			do			1.10	.63	490 39

Main	From C., M. & St. P. Ry. to 160 ft. N.	1893			Brick			2.75	.68	3,028 81
Junction ave	From 14th to 16th	1894			Cedar block			.92	.58	4,203 24
Junction Ave	From 14th to 16th	1894			Repairing			.06	.05½	239 85
4th	From Wisconsin to Bridge.	1895			Limestone block.			1 40	52	1,398 63
3rd	From Main to Lake.	1896			Cedar block			.85	.50	1,269 05
Main	From 6th to 14th	1895			do			1.04¾	.46	25,949 56
Wisconsin	From 4th to 8th	1895			do			.65	.41	5,613 96
Park	From 6th to 14th	1895			do			.65	.41	11,940 57
Dodge and Driver	From Root river to N. Main.	1895			Brick.			1 27	.60	1,770 64
8th	From Washington to C. & N. W. Ry. spur	1896			Cedar block.			.69	43	466 37
5th	From Monument Sq. to College.	1896			do			67	.43	1,438 80
Dodge and Driver		1896			Brick			1 21	.50	321 61
State	From C & N. W. Ry to Forest	1897			Cedar block			.65	.42½	1,960 52
N. W. Ave	From Forest to Prospect	1897			do			.64½	.41½	5,035 84
Washington Ave	From S. Line 14th to Asylum avenue	1897			do			.65	.41½	7,785 20
College Ave	From Water to De Koven	1897			Brick			1 20	.41¾	41,876 71
Washington Ave	From Asylum avenue to 12th street	1901	Crushed lime stone		Crushed lime stone			.75		
Milwaukee Ave	From State street to High street	1901	Crushed lime-stone		do			.75	.42 .50	
N. Main street	From Dodge street to Goold street	1901	Macadam	6 to	brick			1 32	.42 .50	

16

The macadam pavement, which was being constructed in 1901, cost the city 83c. per square yard, including brick gutters four feet wide and four brick cross walks six feet wide at each intersection. Without the brick cross walks and gutters, the cost of the macadam was 75c. per square yard. Where brick are not used for gutters, the combined cement curb and gutter is substituted at a cost of 58c. per running foot. The stone curbing used is Berea sandstone and the cost when dressed and set in place is from 42 to 50c. per running foot. Mr. P. H. Connelly, the city engineer, to whom I am indebted for the above information, says that this sandstone has proved entirely satisfactory. In setting the curbing, Mr. Connelly requires the contractor to place the ends of the adjoining lengths of curb on a single foundation stone 8" x 12" x 5". When the curbing is set in this manner there is little danger of uneven settling.

The brick pavements now being laid have six-inch macadam foundations. In 1901, these pavements were costing the city from $1.30 to $1.32 per square yard with Galesburg brick. This high price was due to a scarcity of brick.

Racine has an ordinance requiring all walks, constructed or reconstructed along paved streets, to be built out of cement, vitrified brick or flag stone and according to specifications prepared by the city engineer. This is highly commendable and other cities will do well to pattern thereafter.

RICHLAND COUNTY.

Richland county is located in the southwestern part of the state within the non-glaciated or driftless area. The surface of the county is very hilly, being typical erosion topography.

The soils in this county are largely medium varieties of clayey loams. Sandy soils occur along the Wisconsin river and also along its tributaries for twenty-five to fifty miles back from their mouths. The Potsdam sandstone outcrops in and underlies the valley portions of the county, while the table land areas are everywhere capped of Lower Magnesian limestone. In two or three places in the western part of the county St.

Brick Pavement Partly Constructed. North Main Street, Racine, Wis.

Brick Pavement in Process of Construction. North Main Street, Racine, Wis.

Peters sandstone is found on the tops of the ridges. Deposits of stream gravel occur in some of the valleys.

The principal sources of stone for road improvements are the Lower Magnesian limestone and the banks of flint gravel which occur along some of the streams. Wherever these occur together they might be combined in such a manner as to make a durable and strong pavement. In some places shaley sandstone layers occur in the Potsdam formation. Wherever these beds are accessible they should be used for temporary improvements to the highways. This shaley sandstone, when properly used, makes a hard surface which is a vast improvement over the sandy roads characteristic of some parts of this county.

RICHLAND CENTER.

(Pop., 2,321.)

The streets in this city have thus far been improved only by grading and graveling. The city has lately purchased a quarry with the intention of using the stone to macadamize the principal streets.

ROCK COUNTY.

This county is located in the southern part of the state on the Illinois boundary line. The surface, with the exception of the Rock River valley, is rolling or hilly. The roads have grades which vary with the character of the topography.

The soils are mainly light clayey and prairie loams. Some sandy loam occurs in the northwestern and southwestern sections. Irregular areas of humus soils occur along the stream channels in the western half of the county.

Glacial drift covers all parts of the county, being heaviest in the northern part where the terminal moraine of the last epoch is found. The drift consists of gravel, sand and boulder clay and occurs in ridges, hills and sheets covering the originally irregular land surface. The gravel and boulders of granitic and trap rocks constitute an important source of supply of stone for road metal.

The underlying rocks are mainly limestone of the Trenton and Galena formations. Irregular areas along the stream channels, in the western part of the county, are underlain with St. Peters sandstone.

The different beds of limestone vary greatly in their suitability for road metal. Only the hardest and most flinty ledges should be used. Much of the stone is undesirable and for this reason granite should be used, at least for the wearing surface.

The following descriptions of the paved streets in Janesville and Beloit will give some idea of these materials and how they wear.

BELOIT.

(Pop., 10,436.)

Beloit has laid 16,000 square yards of vitrified brick pavements and 4,000 square yards limestone macadam. All of these pavements were constructed in 1896, '98 and '99. No pavements were laid during 1900. The following is a list of the streets paved, with the date of completion of the pavement.

Brick Pavement. North of Main Street Bridge, Racine, Wis. Result of not embedding ties in concrete.

Beloit.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction.			Where material was obtained.	Average width of street between curbs.	Cost of construction per sq. yd., exclusive of curb, gutter and underground pipes
			Foundation.		*Surface.*			
			Kind.	Thickness.	Kind.			
State...... ..	From E. Bridge to Broad.	Oct., 1896	Natural subsoil.	1½ in. sand.	Vitrified brick and macadam.	Galesburg, Ill.	2 gutters 15 feet wide with 36 ft. macadam in center.	$.98½
East Bridge...	....	Oct., 1896	...... do	...do ..	Vitrified brick.	...... do	33 ft.	..... do .....
West Bridge ..	From Bridge to 4th..	Oct., 1896	..... do	...do ..	Vitrified brick and madadam.	.... do	15 ft. gutters and 38 ft. macadam in center.	..... do .....
West Bridge ..	From 4th to Bluff ..	Apr., 1899	...... do	2 in. sand.	Vitrified brick.	.... do	48 ft.	..... do .....
School.........	From State to Pleasant.	Nov., 1898	...... do	...do ..	.... do	.... do	56 ft.	..... do .....
State..........	From Broad to C. M. & St. P. Ry. tracks.	Nov., 1898	..... do	... do..	.... do	.... do	66 ft.	..... do .....

The subsoil in Beloit differs considerably in different parts of the city. The streets in the less elevated portions frequently have a very soft subsoil, and unless this is replaced by sand and gravel to a depth of four or five inches, the permanence of the pavement will be greatly lessened. Mr. Swope, formerly city engineer, believes, that by removing four inches of the surface and replacing it with gravel and thoroughly rolling with a steam roller, the softer streets can be put into satisfactory condition for constructing brick pavements. It will be seen by the above table that the macadam pavements on the principal streets are provided with brick gutters 15 feet wide on each side. These wide brick gutters have been constructed on the business streets, where it is customary for the people to tie their teams. It has been clearly demonstrated that a macadam pavement can not long withstand the stamping of the horses hitched along a street. The plan adopted in this city is worthy of careful consideration, and wherever it is planned to construct granite or trap rock macadam on the business streets in the smaller cities, it is very desirable that either brick, stone or concrete gutters be built on both sides. The cost of these pavements, as shown in the above table, has been very moderate, averaging 98½ cents per square yard.

The only imperfections in these pavements are the uneven surfaces which have been caused by settlement where soft places in the subsoil occur. These soft spots are principally the result of the imperfect replacement of the earth in the trenches in which service pipes have been laid. In some instances, however, they are the result of the originally soft condition of the subsoil. Mr. Swope suggests, rightly, that all service pipe trenches, when filled, should be flushed with water in order to insure a proper compacting of the filling material.

A five ton horse roller has been used to compact the subgrade and the different courses of macadam. The city engineer believes that this roller is not sufficiently heavy and that a steam roller of 10 tons weight could be employed to better advantage.

Thus far the cost of maintenance of these pavements has been very little. It is estimated that the 16,000 square yards of

brick and 4,000 square yards of macadam has cost about $450 a year.

When the brick pavements were examined in 1900, it was noticed that the corners and edges of many of the brick were chipped. The brick are laid on a sand cusion, from 1 to 2 inches in thickness, and the joints are filled with clean sand. This method leaves interspaces between the brick, on account of which they are sure to be chipped.

The pavement slopes very steeply toward the openings to the catch basins, making very deep inlets. On the street intersections the brick are laid diagonally across the street.

The sidewalks in this city are constructed out of various materials, prominent among which are vitrified paving brick. An examination of the sidewalks in this city ought to convince one of the fitness of vitrified brick for this purpose.

CLINTON.

(Pop., 871.)

The subsoil in the vicinity of Clinton is a black loam. The streets have been improved by the addition of crushed stone and gravel. Several years ago crushed stone was used, but on account of the expense it has been abandoned. Lately a clayey gravel has been used, which is reported to make a very good road. Limestone gutters are laid next to the curb and through these the water is carried into ditches at the end of the street.

EDGERTON.

(Pop., 2,192.)

The only pavement which this city has is about eighty rods of macadam on the main street which was laid in 1898. The subsoil is very soft, the street being originally laid out through low marshy ground, which was later built up with sand and gravel.

In constructing the street, a part of the sand and gravel was replaced with flat stones, which served as a foundation to the macadam. Owing to the soft condition of the subsoil, the pave-

ment could not be packed sufficiently with a steam roller. However, this street is in very fair condition today and is evidence of what can be done to improve the softest kind of a street by laying a broken stone pavement.

The gutters are built out of paving blocks 4" x 8" x 6". Four inch limestone curbing is laid on both sides of the pavement. The stone used for macadam and gutters was obtained from the Genesee limestone quarry.

JANESVILLE.

(Pop., 13,185.)

Between 1869 and 1894, one mile of cedar block pavement was constructed in this city. It is reported that this pavement wore about 10 years without the necessity of repair, but that it cost about $1,000 per mile a year for cleaning. Such portions of this pavement as have not been removed are in very bad condition today. One block on West Milwaukee street, between High and Academy streets, two blocks on East Milwaukee street, S. Main street between Milwaukee avenue and 1st street, and South River street from Court street to the City Hall, all demonstrate the unsatisfactory character of the cedar block pavement.

In 1895 the city began the construction of broken stone pavements of the macadam and telford types. Up to January, 1902, several miles of macadam pavements had been constructed. In 1899, on W. Milwaukee street, the first brick pavement was laid. Two years later a part of Court street was also paved with brick. On pages 250 and 251 is a list of the streets paved, including those for which contracts have been awarded up to 1902.

Reviewing the table given above, it will be noted that the cost of the macadam pavement has been very low, in some instances not exceeding 30c. per square yard. This, however, does not include the excavation, curb and gutter.

It is to be greatly feared, owing to the use of limestone for the wearing surface of these pavements, that macadam will be in

Brick Pavements.
Cedar Block Pavements.
Macadam Pavements.

as great disrepute 10 years hence as is now the cedar block pavement. There is an abundance of granite and trap rock field stone in the vicinity of Janesville which might be bought and crushed for surfacing the macadam. The use of this stone would increase the cost, but the pavement would be so much better and the cost of maintenance would be so greatly reduced, that its use would be economy on the part of the city.

Janesville should establish a systematic plan of maintenance whereby the macadam can be kept up without being repaired each year. Unless a proper system of maintenance is adopted, the use of limestone macadam will prove an expensive luxury. It has never been possible to construct a limestone macadam pavement which is free from dust and mud. Some limestone is worse than others, but in any event people must expect to suffer from mud and dust unless granite and trap rock are used for surfacing.

Thus far the macadam has been laid nine inches thick at the center and six inches at the curb. It is usually built in two courses, the first of which is five inches thick and the second four inches. The stone is now obtained from a limestone quarry owned by the city. A fifteen ton steam roller is used for compacting and bonding the broken stone.

One of the newly constructed macadam pavements is on Court street between S. Main and Harrison streets. This street has a very steep grade, and a combined cement curb and gutter has been constructed on both sides to remove the surface water. North Main street is paved with limestone macadam having brick gutters on both sides. On one block the brick have been replaced by large stone blocks, forming a gutter six feet wide. The stone blocks have been laid on edge and are too rough to make a suitable gutter. On Dodge street, between South River to High streets, brick gutters have been laid. These gutters are seventeen brick wide and the brick are laid on edge. The joints are filled with sand, although cement grouting should have been used to make them impervious.

Janesville.

Name of street.	Part paved, macadamized, etc	Date	Materials Used in Construction.				Where material was obtained.	Average width of street between curbs.	Cost of construction per sq. yd., exclusive of curb, gutter and underground curbs.
			Foundation.		*Surface.*				
			Kind.	Thickness.	Kind.	Thickness.			
N. Academy....	From Milwaukee to Bluff	1895	Limestone ..	3 to 5 in.	Macadam....	3 in.	In city	40 ft.	....
S. Main.	From S. 1st to Racine	1895-97	...... do	. do ..	Limestone. ..	.. do ...	..... do	....	....
S Main.	From Racine to Carrington	1896	... do	.. do ...	...... do	. do ...	...... do	.. ..	....
N. Jackson......	From Milwaukee to Mineral Point Ave	1896	...... do	.. do . .	.. do	1 to 3 in.	...... do	34 ft.	.36
S. High.	From Milwaukee to Pleasant.	1896	...... do	... do ...	...... do	... do ...	..... do	34 ft.	.29½
N. Main.	From 4th avenue to Prospect	1896	...... do	... do ...	...... do	... do ...	...... do	40 ft.	.39¼
S. Jackson......	One block between Dodge and Pleas'nt	1900	...... do	5 to 8 in.	...... do	4 in	City quarry..	34 ft.	....
S. Second.	From S. Main to Wisconsin	1900	..... do	... do ..	...... do	... do ...	....	30 ft.	....
Court...	FromCourt st bridge to Main street	1901	Macadam .	3 in.	Brick.........	... do ...	....	42 ft.	....
Clark....	From S. Main to Glen Etta.	1901	Limestone. ..	3 to 5 in	Limestone. ..	2 to 3 in.	City quarry..	30 ft.	....
Dodge...........	From S River to Hall.	1901	...... do	.. do ...	...... do	2 to 4 in	. .. do	34 ft.	....
Pleasant	From S. River to High.	1901	...... do	... do ...	..... do	... do ...	...... do	42 ft.	....
W. Milwaukee*	From the river to High	1899	..... do	6 in.	Brick. ...	....	Galesburg....	42 ft	....
S. Main†........	From Carrington to Sharon	1899	...... do	5 to 8 in	Limestone ...	4 in.	City quarry ..	42 ft.	....
Academy........	From Milwaukee to Pleasant	1901-02	...... do	3 to 6 in.	...... do	3 in.	...... do	42 ft.	....
Marion....	From Milwaukee to Pleasant.	1901-02	...... do	... do ...	...... do	... do ...	...... do	42 ft.	.35¼

*Total cost of construction, $10,714.44. †Total cost of construction, $2,482 18.

Franklin	From Dodge to Pleasant.	1901-02	do	do	do	do	do	42 ft.	
Pleasant	From High to Lynn.	1901-02	do	do	do	do	do	42 ft.	
S. 3rd	From Main to Jackson.	1901-02	do	do	do	do	do	30 ft.	
S. 2nd	From Wisconsin to East.	1901-02	do	do	do	do	do	42 ft.	.50
Bluff	From E. Milwaukee to N. 1st.	1901-02	do	do	do	do	do	42 ft.	
Court	From Main to Harrison.	1901	do	5 in.	do	do	do	42 ft.	
W. Milwaukee	From High to Academy				Cedar block				
S. Main	From Milwaukee Av., to S. 3rd street.				do				
S. River	From Court to City Hall.				do				

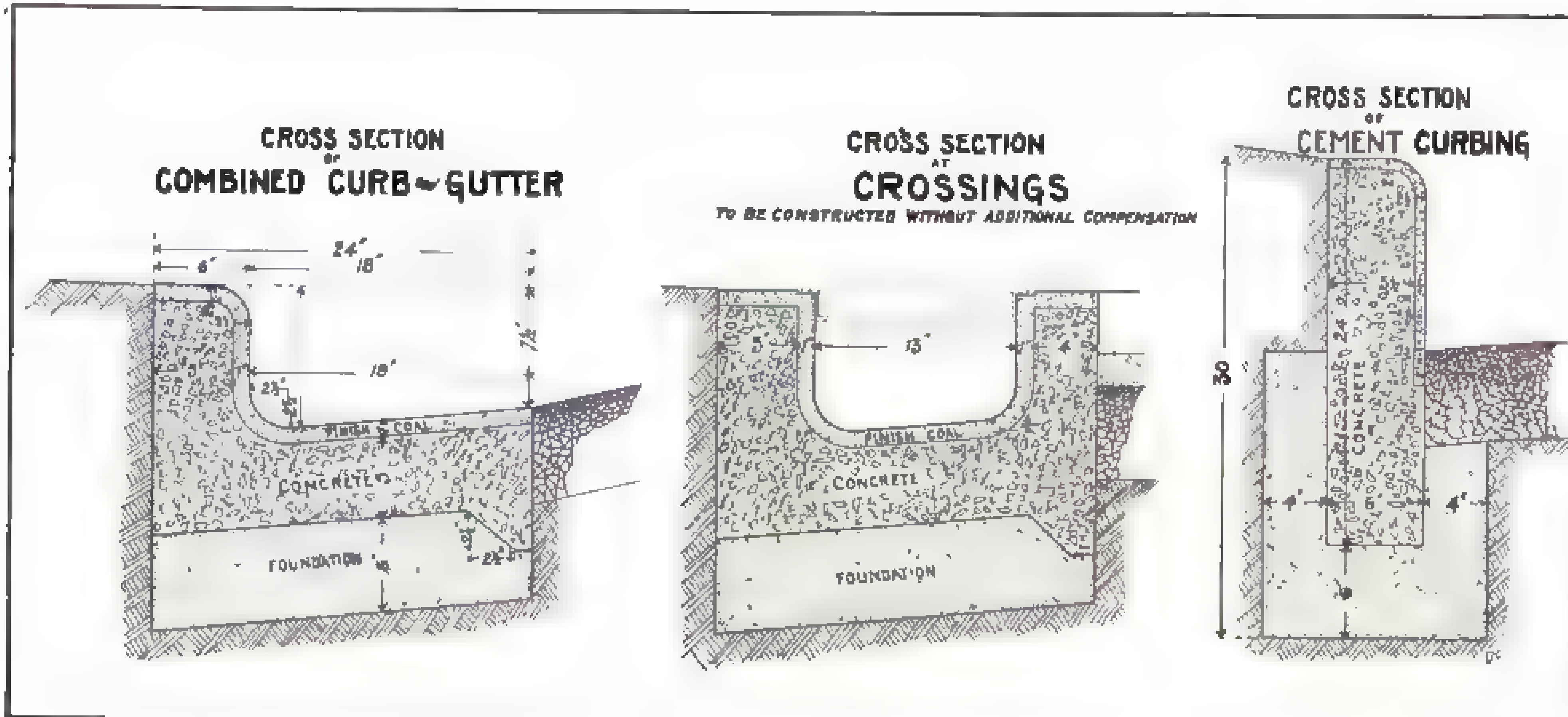
South 2nd street, which was paved in 1900, is one of the best looking streets in the city. The macadam pavement has a crown which is in good proportion to the width of the street, and a combined cement curb and gutter has been laid on both sides.

The brick pavement on West Milwaukee street has only been down two years and it is scarcely possible for one to express an opinion as to its probable durability. It shows some evidence of wear, but, perhaps, no more than could be expected. The brick were laid on a concrete foundation and had the joints been grouted with cement, instead of sand, they would probably show much less deterioration than they do.

ST. CROIX COUNTY.

St. Croix county is located in the western part of the state on the St. Croix and Mississippi rivers. The surface of the county is somewhat diversified, portions of it being level and prairie like, while other parts are hilly and rolling. The soils are mainly clayey and prairie loams. A narrow belt of sandy soil extends through the county from northeast to southwest along Willow and Apple rivers. The eastern part of the county is covered with a thin mantle of drift, resulting from the deposits of the earlier glacial epochs. The northwestern part of the county is covered with a considerable thickness of drift of the last glacial epoch. Two belts of ridges and hills, composed mainly of drift, extend in a northeast-southwest direction through the western part of the county. The drift consists of gravel, sand and boulder clay, from which considerable quantities of excellent road metal might be obtained.

The greater part of the county is underlain with Lower Magnesian limestone. In the western part the underlying rock is mainly Potsdam sandstone, while in the south central portion St. Peters sandstone and Trenton limestone outcrop over a considerable area. Of these formations the Lower Magnesian contains stone which is best suited for road metal. The use of this



Cross Sections of Curbing and Gutters, Janesville, Wis.

stone in conjunction with granite or trap rock, which can be obtained from the glacial deposits, ought to provide excellent broken stone pavements in this county.

GLENWOOD.

(Pop., 1,789.)

Mr. C. H. Kellar reported in 1899 that the streets of this place had never been improved with broken stone or any other kind of paving material. The only improvement has been in the way of grading.

HUDSON.

(Pop., 3,259.)

No macadam or other permanent pavement has been constructed in Hudson. Some of the streets have been improved by adding to the surface a layer of mixed sandstone and shale which is obtained from quarries in the Potsdam sandstone, which outcrops in this vicinity. This so-called shale is the same as that which in Eau Claire is mixed with gravel and applied to the streets. The sand rock and shale are broken up and spread evenly over the streets, where it is ground and packed by the traffic. The streets thus improved are hard and smooth during dry weather, although somewhat dusty when subjected to heavy traffic. This is one of the best materials which can be obtained in this state for temporarily improving the streets of the small towns or the country highways. There is an abundance of this so called shale in this region and it ought to be used more generally in improving the highways of this part of St. Croix county.

NEW RICHMOND.

(Pop., 1,631.)

None of the streets of this village have thus far been paved. Plans are now being made to macadamize some of the more important highways. The soil in this vicinity is black loam for about two feet in depth. Underneath this is found clay and then, for about three feet, a deposit of sharp sand.

It is expected that the streets will eventually be macadamized with crushed field stone, using the smaller sizes to build cobble stone gutters.

SAUK COUNTY.

Sauk county is located in the southwestern part of the state on the Wisconsin river. The Baraboo bluffs and the terminal moraine in the eastern part of the county, combined with the stream erosion in the western driftless portion, makes the surface of the county as a whole very hilly. The soil along the Wisconsin river and in the eastern and northern sections of the county, is a sandy loam, while that in the remaining area is essentially medium and light varieties of clayey loams. Occasional areas of humus soils, composed mainly of muck and peat, occur along the different stream channels. The eastern part of the county is covered with a heavy mantle of drift, comprising a portion of the terminal moraine of the last glacial epoch. The drift in this region consists of boulder clay, sand and gravel, constituting a valuable source of materials for road construction.

The Baraboo bluffs, which extend in a general east and west direction through the middle of the county, consist mainly of quartzite. Small areas of porphyry and granite occur in this region, but the outcrops are not extensive. The quartzite of these bluffs constitute the most extensive supply of stone in the county for road metal. Two crushing plants have been erected for crushing this stone,—one at Ableman and the other at Devil's Lake. The stone from these quarries is shipped to various parts of the state. The crushing plant, located at Ableman, is shown in the accompanying illustrations.

The ridges and bluffs in the western part of the county are capped with Lower Magnesian limestone. The harder beds of this limestone might be used to advantage with the quartzite, as a bonding constituent.

Crushing Plant. Wisconsin Granite Co., Ablemans, Wis.

BARABOO.

(Pop., 5,751.)

On January 1st, 1901, Baraboo had four blocks of cedar block pavement and ten blocks of macadam. The cedar block was constructed about 1891, and is reported by Mr. Kirchoffer, the city engineer, to be in poor condition. It costs about $500 a year, with labor at 15c. per hour, for cleaning. The first macadam pavement was constructed in 1894, since which time additions have been made in 1897, 1899 and 1900.

The width of the improved streets between curbs, ranges from 33 feet to 50 feet. The subsoil in this locality is mainly a sandy clayey loam, varying locally within short distances. The macadam is laid to a thickness of eight inches and follows the usual specifications for pavements of this kind. The stone used is quartzite quarried at Devil's Lake and Ableman.

The gutters in the residence portion of the city have the best shape and are constructed on the best plan of any which have been examined in this state. The shape of these gutters and their relation to the pavement and park areas, are well shown in the accompanying diagrams and cuts. It has been pointed out in another place that, on residential streets, heavy curbing is unnecessary, and for this reason the shape of the gutter should be such that it will meet and conform to the grade of the street on one side and to the park area on the other.

In 1900, four blocks of macadam were laid on 4th avenue. This pavement was 30 feet wide and had a thickness of eight inches. Including gutters it cost $5,000.

The only difficulty which has been experienced in constructing these macadam pavements has been in bonding the quartzite. This difficulty, however, has been overcome by mixing a small quantity of limestone screenings or plastic clay with each layer of stone. When thus constructed, the pavement has proven very satisfactory. Under ordinary conditions, it is clean and noiseless and requires the expenditure of a very small sum of money for maintenance and repair. At the present time the city is paying very little attention to keeping up the pave-

ments already constructed. These should be given almost as much attention as the unpaved streets.

KILBOURN.

(Pop., 1,134.)

Improvement of the streets in this village has been thus far confined to grading and graveling. Some sandstone curbing has been used but the surface water is removed by the natural drainage of the streets. Excellent sandstone for curbing and for cross walks and sidewalk purposes is obtained from a quarry located near the city.

LODI.

(Pop., 1,068.)

None of the streets of this village have been paved although most of them have been graveled.

REEDSBURG.

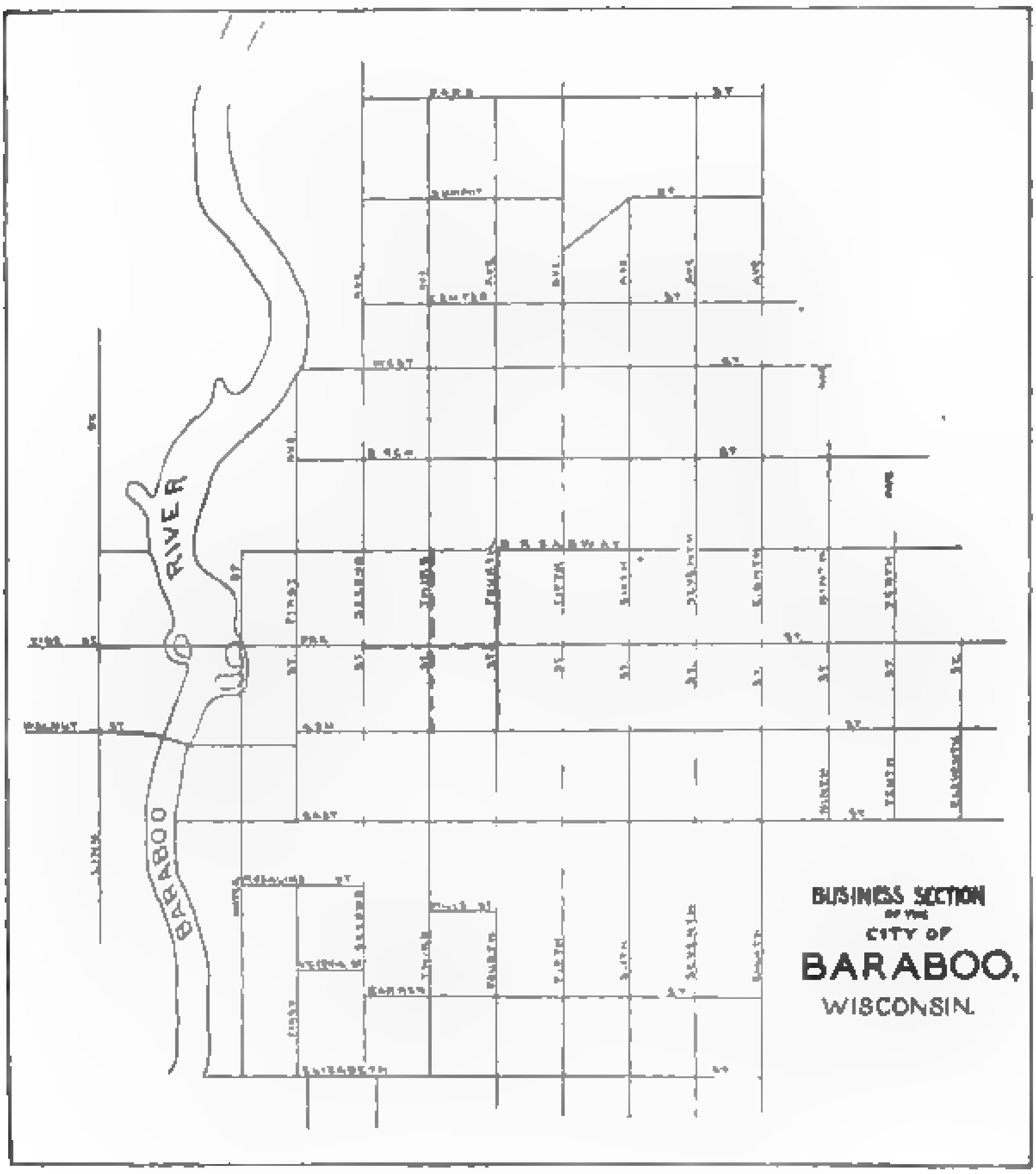
(Pop., 2,225.)

The only pavement in this city consists of five blocks of vitrified brick. The following table shows the streets on which this pavement was constructed and the cost of constructing the same.

Reedsburg.

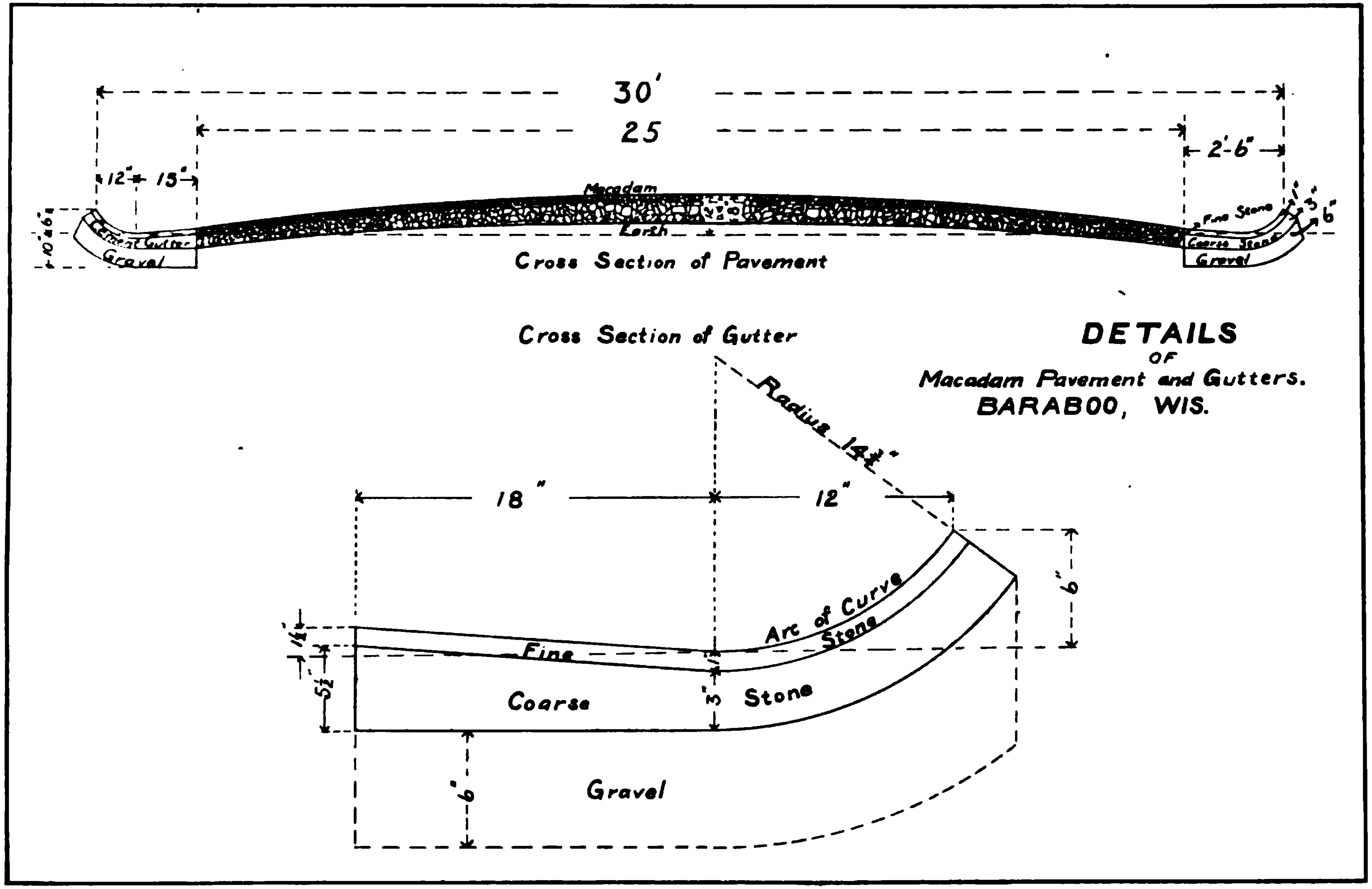
Name of street.	Part paved, macadamized, etc.	Date.
Main	Three blocks	1899
Walnut	Two blocks	1899

Name of street.	Materials Used in Construction.			
	Foundation.		*Surface.*	
	Kind.	Thickness.	Kind.	Thickness.
Main	Sand	2 in.	Brick	4 in.
Walnut	Sand	2 in.	Brick	4 in.



Cedar Block Pavements.

Quartzite Macadam Pavements.



Details of Construction of Macadam Pavement and Gutters, Baraboo, Wis.

Name of street.	Where material was obtained.	Average width of street between curbs.	Cost of construction per sq. yd, exclusive of curb, gutter underground pipes.
Main......	Galesburg, Ill	71 ft.	$1.15
Walnut	Galesburg, Ill	46 ft.	1.15

The subsoil in this city is in part a sandy loam and in part a heavy black muck. During dry weather the streets are firm and smooth, but in the spring they are usually very soft. The foundation for the brick pavement consisted of two inches of sand, covering the sandy, mucky subsoil. The brick were laid on edge crosswise of the street and the joints were filled with sand. The probability is, that if there should be any very heavy teaming on this pavement during a continued wet season, depressions would be formed on the surface. It is also possible that the frost in the spring may heave and displace some parts of the pavement.

SAUK CITY.

(Pop., 810.)

The streets in this place have been improved by the addition of gravel obtained in the village. Water, Bryant, Jackson, Polk and Van Buren streets have been improved in this manner.

The subsoil is sand. The rain water is removed entirely by surface drainage. Stone curbing and gutters are laid along some of the streets. The stone is obtained from a quarry located near the village.

SAWYER COUNTY.

Sawyer county is located in the north central part of the state. It is entirely within the glaciated region and is underlain with granitic, gneissoid and trap rocks, belonging to the pre-Cambrian formations. Lakes and streams are abundant throughout the county. The topography of the western and

northwestern parts is rolling and hilly, being characteristic of morainal deposits. The eastern and southeastern sections of the county have a much less rugged surface.

The soils in this county are largely light clayey loams. Areas of sand of considerable extent occur in the western and northwestern parts. Irregular areas of humus soils, composed mainly of muck and peat, are found in different sections of the county.

The principal sources of road metal are the glacial gravels, the boulder deposits and the outcrops of igneous rocks, especially those in the northwestern portion.

SHAWANO COUNTY.

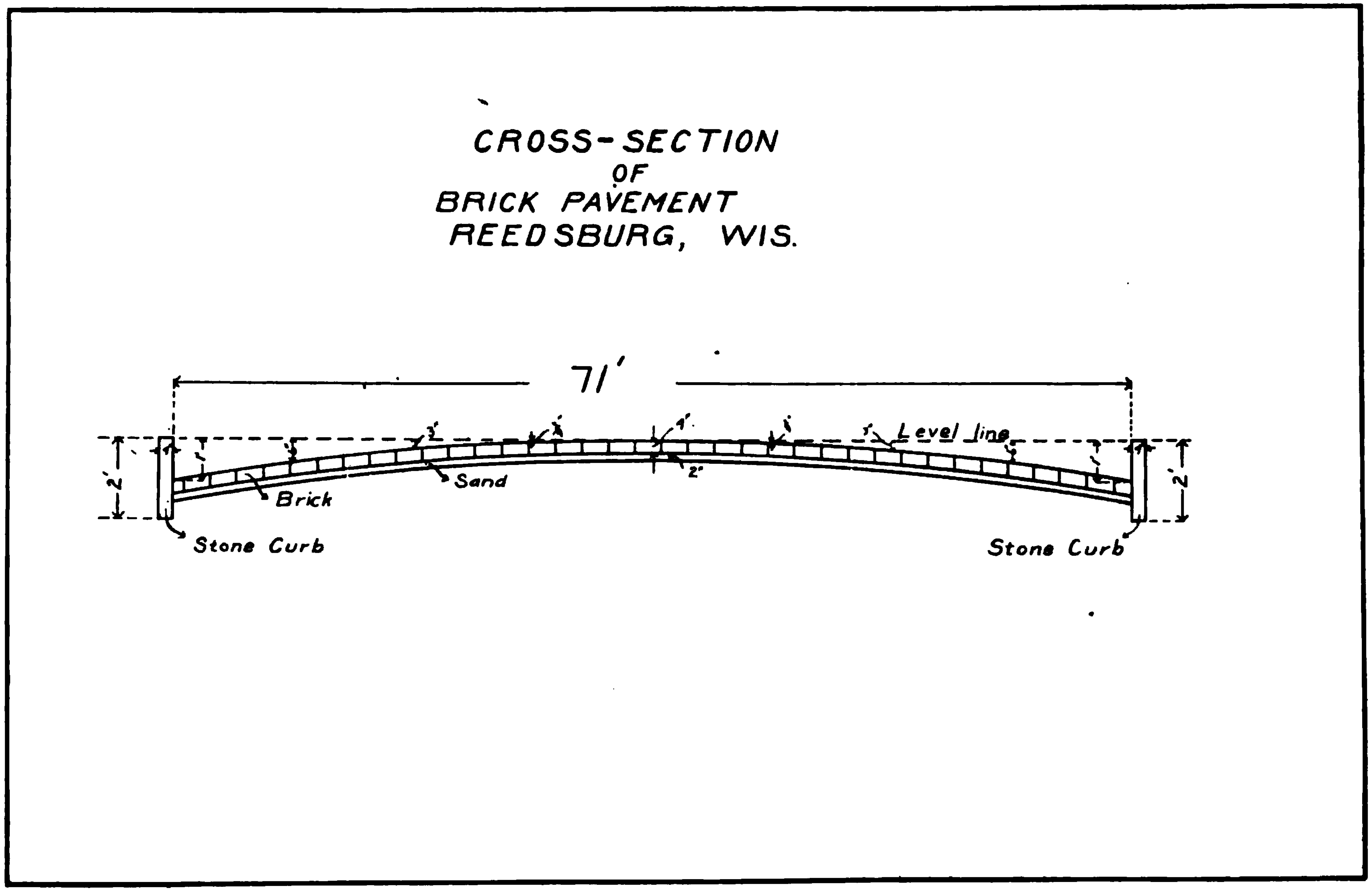
Shawano county is located in the northeastern part of the state directly west of Green bay. The surface of the country is more or less rolling and hilly. The county is entirely within the glaciated region and the surface is consequently covered with a variable thickness of glacial drift, forming hills and ridges. The terminal moraine of the last glacial epoch, which passes through the northwestern corner of the county, constitutes the watershed between the great lakes and the Mississippi river.

The soils in this county are mainly light clayey loams. In the eastern part of the county, especially along the Wolf river, occur considerable areas of sand and sandy loams. Irregular areas of humus soil, composed mainly of muck and peat, are found along many of the stream channels.

The western and northern portions of the county are underlain with granitic and gneissoid rocks belonging to the pre-Cambrian formations. The central part is underlain with sandstone of the Potsdam formation, and the eastern portion with Lower Magnesian and Trenton limestone and St. Peters sandstone.

The main sources of rock for road metal are glacial drift, which covers all parts of the county, the igneous rocks in the

Quartzite Macadam Pavement, Baraboo, Wis.



Cross Section of Brick Pavement, Reedsburg, Wis.

northwestern and the limestone in the eastern part. The use of limestone in conjunction with granite rock will provide very desirable pavements for this county.

SHAWANO.

(Pop., 1,863.)

This city has about three miles of streets which have been covered with crushed stone. The drainage facilities of this place are good. The soil is sandy, making one of the best of foundations for macadam pavement.

SHEBOYGAN COUNTY.

Sheboygan county is located in the east central part of the state on Lake Michigan. This county is entirely within the glaciated region and consequently the surface is covered with a variable thickness of drift. The topography of the county is broken and hilly in the western and northwestern portions as a result of heavy morainal deposits. The area adjacent to the lake has a less broken surface, being a part of a former extension of the lake bed. The soils are mainly light and heavy clayey loams. A small strip adjacent to the lake in the southern part of the county is covered with sandy soil.

The underlying formation is Niagara limestone. This stone outcrops in different parts of the county and is used at various places as a road metal.

The chief supply of local stone for road construction must come from the glacial drift in the western part and from the Niagara limestone which outcrops in many parts of the county. The limestone should be carefully selected, only the harder and more durable beds being suitable for road metal.

PLYMOUTH.

(Pop., 2,257.)

The streets of Plymouth are improved by the addition of crushed granite and trap rock. The stone is obtained in the

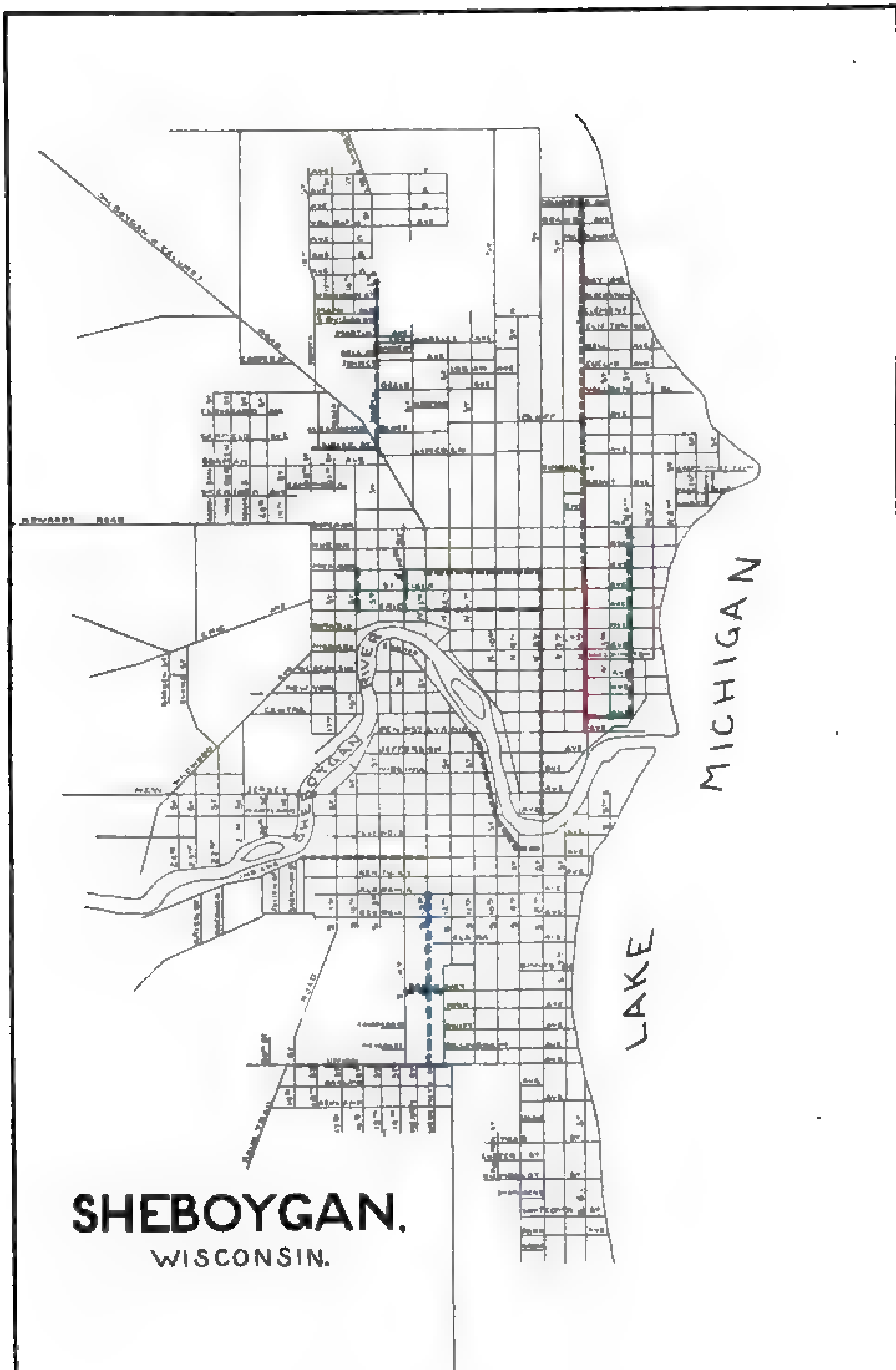
form of very coarse gravel and small boulders from a gravel pit and run through a crusher without sorting. The crushed stone is being used on the streets the same as gravel. No record is kept of the mileage or of the cost of construction, cleaning or repairing, wherefore these are omitted from this report.

The use of coarse gravel for the manufacture of crushed stone is practiced in some of the eastern cities and provided the boulders are not too small is entirely satisfactory.

SHEBOYGAN.

(Pop., 22,962.)

Sheboygan has about 3.47 miles of cedar block pavement, 15 miles of graveled streets and about a mile of granite top macadam. The following table gives a list of the streets paved, with miscellaneous information concerning the method of construction, cost, etc.



Granite Top Macadam Pavements.

Cedar Block Pavements.

Gravel

Sheboygan.

Name of street.	Part paved, macadamized, etc.	Date	Materials Used in Construction. Foundation. Kind.	Foundation. Thickness.	Surface. Kind.	Surface. Thickness.	Where material was obtained.	Average width of material between curbs.	Cost of construction per sq. yd., exclusive of curb, gutter and underground pipes	Total cost of construction.
N. 8th	From Jefferson to Michigan.	1890	Hemlock pl'k	2 in.	Cedar block .	8 in	Northern Wisconsin	56 ft.	$0.88	$18,958 00
Michigan Ave	From N. 8th to N. 13th.	1892	... do ...	. do ..	.... do	. do ..	..... do	56 ft.	1.10	14,108 07
Indiana Ave..	From S. 13th to S. 18th	1892	... do	. do .	.... do	.. do .	.. . do	56 ft. 2 blks. 48 ft.—3 blks.	.96	12,715 00
N. 5th	From Jefferson to Maryland	1892	.... do	. do .	.... do	.. do	..... do	56 ft.	1.15	8,816 86
S. Water. ...	From Penn to 8th ..	1892	..... do	. do .	.. .. do	.. do	..... do	No curb (Ave about 60 ft.)	.78	10,815 58
N. 6th..	From Michigan to City Limits.	1893	.... do ..	do	.. do	6 in.	...... do	30 ft. (40 ft. 2 blocks.)	.61½	8,987 34
Erie	From N. 8th to N. 13th.	1892	Clay.	....	Gravel........	9 to 5.	Local	48 ft.	.65 cu. yd	1,014 00
N. 4th.........	From Superior to Center	1892	Sand	......	..... do	. do .	. ... do	48 ft. 36 ft.	.83 cu. yd	1,666 25
N. 14th........	From Superior to Erie.	1892	Clay..... ...	....	.... do	. do ..	.... do	36 ft.	.74 cu. yd	787 36
N. 15th	From Calumet Rd. to City Limits.	1893	Clay........	....	...... do	. do ..	..... do	40 ft.	.85 cu. yd	2,856 00
S. 13th	From Alabama to Union	1895	Sand.	.... .	.... do	.. do .	...... do	30 ft.	.70 cu. yd	1,435 00
N. 16th.	From Erie to Mehrton.	1897	Clay	. . .	...... do	.. do ..	...... do	48 ft.	.75 cu. yd	1,206 00
Sibley C. F...	Entire...............	1897	... .. do	. . .	..... do	.. do ..	...... do	36 ft.	.60 cu. yd	430 00
Broadway. ..	From S. 12th to S. 14th.	1899	..... do	......	...... do	. do .	Local banks .	48 ft.	.70 cu. yd	449 40
Union	From S. 12th to S. 19th.	1899	...... do	......	..... do	. do .	...... do	30 ft.	.64½	2,750 75
Center	From 6th to 4th.	1900	...... do	... ...	...... do	. do .	.... do	36 ft.	.80	714 00
N. 8th.........	From Michigan to Penn.	1900	.... do	....	Macadam ...	12 clay 3 gran.	Both quarry .	30 ft.	.97	15,397 00

Mr. C. U. Boley, city engineer, to whom I am indebted for the above information, says: "Our experience with cedar block satisfies us that it should be placed at the foot of the list of paving material. Its only recommendation is the cheap first cost. I shall recommend brick for business streets and granite top macadam for residence streets wherever cedar block has to be rebuilt."

During 1900, the city of Sheboygan began the construction of macadam pavements, using limestone for the foundation and granite for the surface. The macadam pavement which was constructed on North Sixth street, between Michigan and Pennsylvania avenues, is one of the best which has been constructed in Wisconsin. The street is built out of the very best limestone and granite; is provided with combined cement curb and gutter; and was built with the greatest care both as regards spreading and rolling. The only provision which it is necessary for the city to make at this time is for systematic maintenance. It is very important that a macadam pavement should be kept in such a condition as not to need repairing. The macadam pavement constructed in 1900 ought to be in as good condition ten years hence as it is today, if the section system of maintenance, outlined elsewhere, is adopted. The adoption of the recommendation of the city engineer, that cedar block be replaced with brick on the business streets and granite top macadam on residence streets, will, with a proper system of maintenance, give Sheboygan the most desirable pavements that can be obtained.

SHEBOYGAN FALLS.

(Pop., 1,301.)

The principal streets of this city have been macadamized with limestone from the quarry in the city. The stone is somewhat soft and grinds into a fine powder under the wheels of the vehicles.

There are a great many granite and trap rock boulders scattered over the fields in this vicinity and the durability and cleanliness of the pavements might be very greatly increased by crushing these rocks and using them for top dressing.

Granite Top Macadam Pavement. Michigan Avenue, Sheboygan, Wis. Built in 1901.

Cedar Block Pavement. North Eighth Street, Sheboygan, Wis. Built in 1892.

TAYLOR COUNTY.

Taylor county is located in the central part of the state. The surface is rolling and hilly as a result of stream erosion combined with glacial erosion and deposition. The county is entirely within the glaciated region and the underlying rocks are chiefly of the granitic and gneissoid varieties.

The soils are mainly the lighter and medium varieties of clayey loams. A considerable area in the western portion along the Yellow river has a sandy soil. Some sandy soil is also found along the Big Rib river in the southeastern part.

The chief sources of rock for road construction are the glacial drift, which covers the entire county, and the outcrops of granitic rocks, occurring mainly along the stream channel. There is an abundance of gravel in some sections which can be used to advantage for the temporary improvement of the roads.

MEDFORD.

(Pop., 1,758.)

The streets of this city have not yet been improved with macadam or other pavements of a permanent character. There is an abundance of excellent gravel in this vicinity which has been used to temporarily improve the streets. The sub-soil in this place is a heavy clay loam.

Plans are now being made to build 2,000 feet of pavement on the main business thoroughfare, known as Front street. It is proposed to use Kettle river stone for curbing and gutters. The pavement will be built out of crushed granite or trap rock.

Granite and trap rock are abundant throughout this region and there is little excuse for the city not having excellent macadam pavements. If the city owned a crusher and street roller, field stone could be purchased from the farmers and by a proper application of the available funds, all the important streets might soon be macadamized.

TREMPEALEAU COUNTY.

Trempealeau county is located in the western part of the state on the Mississippi river. The northern part of the county, which is within the glaciated portion of the state, is covered with a thin mantle of drift. The southern two-thirds of the county is within the driftless area and the surface is a succession of hills, ridges and valleys such as characterize that section of the state.

The soils are mainly sandy loams. Narrow belts of sand occur along the Black, Trempealeau and Mississippi rivers, while prairie loams occupy several small areas in the southern portion.

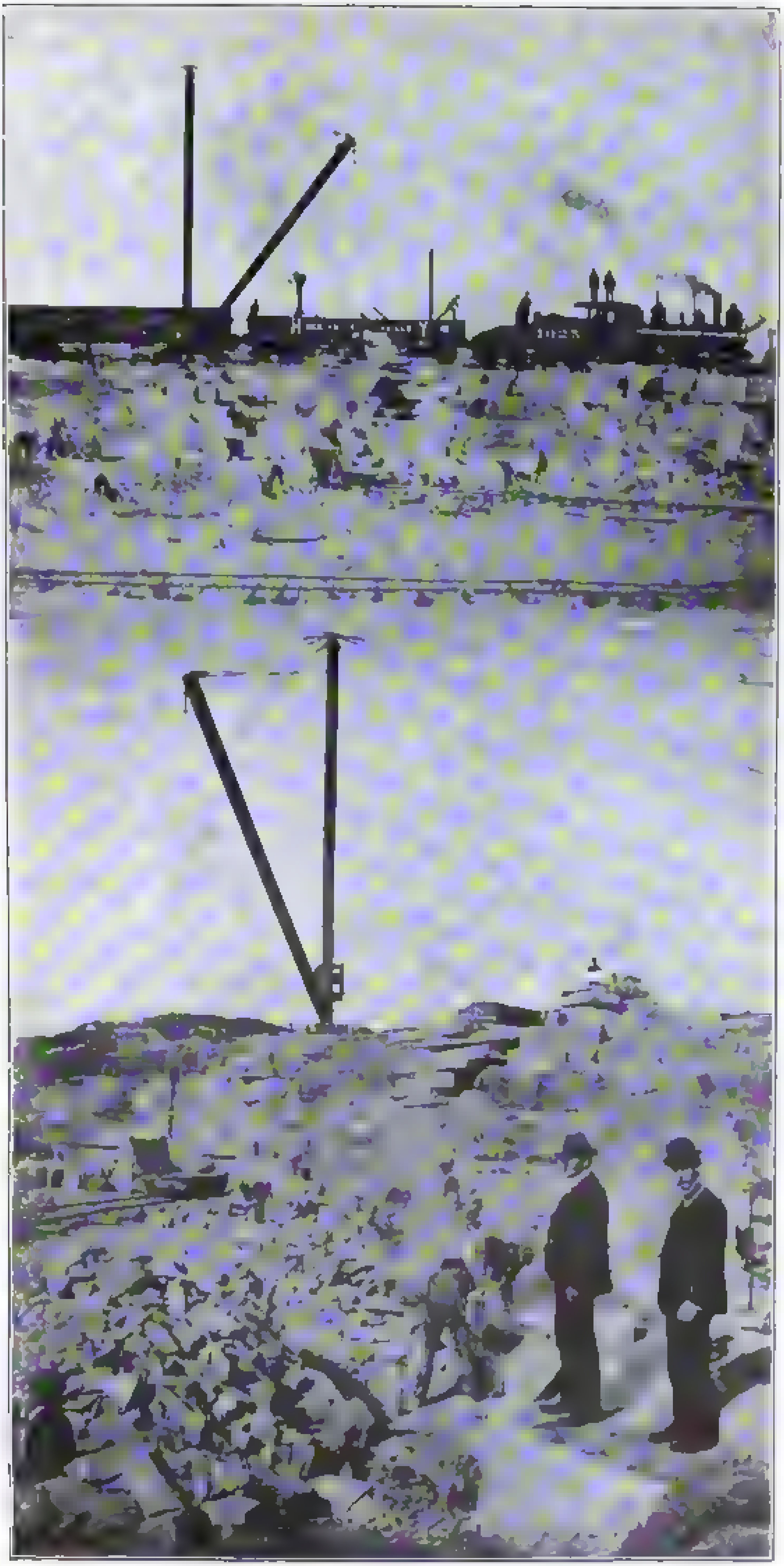
Two or three small irregular ridges in the south central part of the county are capped with Lower Magnesian limestone. Outside of this, the underlying rock is entirely sandstone of the Potsdam formation.

Shaley layers of Potsdam sandstone combined with gravel and boulders from the drift in the northern part of the county constitute practically the only local source of stone for road metal. Gravel banks, which occur along some of the stream channels, furnish small quantities of stone suitable for temporary road improvements.

ARCADIA.

(Pop., 1,273.)

On January 1st, 1901, Arcadia had 3,050 lineal feet of macadamized streets. The first pavement, 300 feet long, was constructed on Main street in 1896. All of the pavements have been built out of native limestone and flint rock. The subsoil at this place consists of sand from one to three feet in thickness, which provides an excellent foundation for a macadam pavement. Since 1896, the village has continued to improve a small section of the streets each year until, at present, she has nearly two-thirds of a mile of macadam pavement. On Main and Grant streets, combined, there are 2,486 feet of macadam,



Menomonee Falls-Lannon Stone Company. Quarries at Lannon, Wis.

on Washington street, 264 feet and on Commercial street, 200 feet. The width of the streets between curbs ranges from 40 to 51 feet, all of which is macadamized.

The city owns its own crusher and buys flint and limestone rock at $3.30 per cord, delivered in the city. Sandstone for filling and grading is obtained half a mile from the center of the village and costs 2 cents per load in the bank. Limestone curbing, 4 inches thick, 18 inches wide and 4 to 10 feet in length has been obtained from Winona at a cost of 35 cents per lineal foot set in place. The cost of improving streets, including grading, curbing and macadamizing, has ranged from $1.11 to 74 cents per square yard, the latter being the cost of paving 300 feet of Main street in 1900.

The quarry from which the stone is obtained is located directly north of the city and consists of alternating layers of flint and limestone. The so-called flint is a coarse sandstone which has been thoroughly indurated. When thoroughly mixed with the soft limestone the wearing capacity of the pavement is materially increased.

Mr. George Mathys, the clerk of the village, informs me that thus far no difficulty has been experienced in the use of macadam, and very little money has been needed to keep the streets in excellent condition. The traffic is naturally light and the expense of maintenance is correspondingly small.

It is to be hoped that the authorities will appreciate the importance of keeping up these pavements, in the same manner as has been recommended for the larger cities. It will prove as economical for a village to care properly for her pavements as it is for a city.

VERNON COUNTY.

Vernon county is located in the southwestern part of the state, on the Mississippi river. This county lies wholly within the driftless area and throughout its extent is a succession of flat top ridges and valleys. On the ridges the underlying rock is

mainly Lower Magnesian limestone, although some of the higher ridges in the western part are capped with St. Peters sandstone and Trenton limestone. The valleys and the main streams are underlain with Potsdam sandstone.

The soils in this county are mainly light clayey and prairie loams, except along the Mississippi and tributary rivers, where the soils are of a light, sandy nature. The clayey loams on the ridges contain numerous residual boulders of flint. This flint has in many cases been carried in the stream channels and collected into banks which now constitute a source of supply for temporary road improvements.

The flint boulders and gravel, when crushed and used with the harder limestone of the Lower Magnesian formation, constitute the most desirable local supply of stone for road metal. The crushed limestone and flint when properly used ought to make a pavement suitable for most of the towns, villages and cities in this county.

VIROQUA.

(Pop., 1,950.)

This city has one block of limestone block pavement, constructed in 1895, and about two miles of broken stone pavements. The stone block pavement has needed no repairs thus far and is reported to be in good condition. An examination of the pavement, however, shows that the surface is very rough and if kept clean would be disagreeable to drive over. This pavement is on a side street and is only called on to sustain light business traffic.

The first broken limestone pavement was laid in 1894. In 1900 the city resurfaced a greater part of this pavement with six inches of crushed rock, and with the exception of a slightly uneven surface it is reported to be, at present, in good condition. The city has lately purchased a quarry and expects to increase rapidly the mileage of macadam.

The broken stone pavements which were constructed in 1894 were not built according to the usual method of constructing macadam pavements. No attempt has been made to keep up

the pavement so as to avoid the necessity of making extensive repairs.

The limestone which is quarried in this vicinity comes from the Lower Magnesian limestone formation. The beds of this formation differ considerably in their suitability for macadam pavements. For this reason special care should be exercised in selecting the best stone in the quarry for this purpose. The soft beds which frequently occur in this formation should be avoided. If possible some of the hard flint rocks, known as "nigger heads," should be crushed and used with the limestone. Two-thirds of the wearing surface should be of flint or a similar hard rock.

The use of granite or trap rock for top dressing would of course be preferable to either flint or limestone. However, the freight rate on the crushed granite is probably too high to warrant its use. It is thought, however, that with care in the selection of the limestone, the use of some flint and the adoption of a proper system of maintenance some very excellent macadam pavements can be built. It should be remembered that a thickness of six or seven inches of crushed rock is ordinarily sufficient for a residence street; that the pavements should not be over thirty feet wide; and that gutters of stone, concrete or brick should be laid to carry off the storm water.

VILAS COUNTY.

Vilas county is located in the northern part of the state on the Michigan–Wisconsin boundary line. The surface of the county is underlain with heavy deposits of glacial drift. The county is dotted with hundreds of lakes and innumerable small swamps or marshes. With the exception of occasional irregular areas of humus soils, the county is covered with sandy loams.

The underlying rocks are supposed to be altogether of the granitic and gneissoid varieties, however, on account of the thickness of the drift, very few outcrops occur in the county.

An inexhaustible supply of stone for road metal is found in the gravel and boulders of the drift deposits.

WALWORTH COUNTY.

Walworth county is located in the southeastern part of the state on the Illinois boundary line. The county lies within the glaciated region of the state and is traversed in the southern, western and northern parts by the terminal moraine of the last glacial epoch. The surface of most of the county is rolling and somewhat hilly.

The soils are light clayey and prairie loams. Irregular areas of humus soils, composed mainly of muck and peat, are found in different parts of the county. The underlying rocks are mainly limestone belonging to the Niagara and Galena formations. Unimportant outcrops of the Hudson River shale occur in the western portion.

The chief sources of road metal are the quarries in the Galena and Niagara limestones and the boulders and gravel of the glacial drift. The boulders in the drift consist very largely of granitic and trap rocks, which, when used with the limestone, constitute an excellent material for broken stone pavements.

DELAVAN.

(Pop., 2,244.)

All of the streets in this city have been improved with gravel, spread upon the natural soil foundation. Up to January 1st, 1901, no pavements had been laid in this city.

The advantages of a macadamized over a gravel street are sufficient, it is thought, to warrant the additional expense attached to the construction of the former. This city ought to experience no difficulty in obtaining field stone, in the shape of granite and trap boulders, suitable for crushing and out of which the very best macadam pavement can be constructed.

LAKE GENEVA.

(Pop., 2,585.)

In 1899 the city clerk reported that up to that date none of the streets had been macadamized or otherwise permanently improved. The streets have been graded and graveled.

No information could be obtained bearing on the cost of graveling or the approximate cost of maintenance.

WHITEWATER.

(Pop., 3,405.)

About three miles of streets have been macadamized with limestone. The first of these pavements was laid in 1885 and the last in 1898. It costs annually about $40 per mile for cleaning these pavements. The streets are reported to be in good condition and the first pavement constructed was first repaired in 1898. The city also has six and a half miles of graveled streets, which cost about $125 per mile per year for repairing. These streets are reported to be in fair condition.

The macadam streets could be very greatly improved by surfacing with two or three inches of fine crushed granite or trap rock. There should be an abundance of these rocks in the shape of field stone in the vicinity of Whitewater, and they ought to be used for top dressing in preference to the limestone. The subsoil is largely sand or gravel, providing excellent conditions for the construction of an ideal macadam pavement.

The following table gives all the information obtainable concerning the streets of this city.

Whitewater.

Name of street.	Date.	Materials Used in Construction. Foundation. Kind.	Surface. Kind.	Surface. Thickness.	Where material was obtained.	Av. width of street between curbs.
Main	1887 to present time.	Considerable	Crushed limestone.	9 in. at center 5 in. at gutter	About 1 mile from city.	30 ft.
Center		sand	do		do	
Whitewater		on main	do		do	
Milwaukee		streets.	do		do	
N. 3rd			do		do	
Main		Natural				30 ft.
State		soil rounded			In the city	do
Jefferson		up and			do	do
Milwaukee		covered,			do	do
Newcomb		with clay,			do	do
Pierce		sand or			do	do
Janesville		gravel.			do	do

WASHBURN COUNTY.

Washburn county is located in the northwestern part of the state within the glaciated region. The surface of the county is broken and hilly as a result of the character of the rocks and, in the southeastern part, the thickness of the morainal deposits. Three distinct moraines traverse the country in a northeast-southwest direction. These moraines consist of irregular ridges and hills of boulder clay, gravel and sand. The soils are mainly sand and light clayey loams. The latter occur mainly in the southern and northeastern portions of the county.

The underlying rocks are entirely of the granitic, gneissoid and trap varieties belonging to the pre-Cambrian formations. Two small areas, one in the northwestern part and the other in the southern, are underlain with Potsdam sandstone. The broad belt of Keweenawan rocks, which extend through the central and northern portions of the county, is composed very largely of melaphyre diabase, diorite and other rocks of the trap variety.

The outcrops of Keweenawan rocks, combined with the glacial gravel and boulders strewn promiscuously over the county, constitute the most important source, as well as an inexhaustible supply, of stone for road metal.

WASHINGTON COUNTY.

Washington county is located in the southeastern part of the state. The surface of the county is rolling and hilly. A range of hills extends through the central part of the county in a somewhat southwesterly direction, constituting a part of the terminal moraine.

The soils of this county are largely clayey loams of the light and medium varieties. Calcareous sandy loams occupy an irregular area in the northern and central portions of the county.

With the exception of a few small outcrops of Hudson River

shale in the western part, the rock underlying the county is entirely Niagara limestone.

The chief sources of supply of stone for road metal are the gravel and boulders of the glacial drift and the limestone of the Niagara formation. The granitic and other igneous rocks of the glacial drift can be crushed and combined with the limestone in such a manner as to form excellent pavements.

SCHLEISINGERVILLE.

(Pop., 549.)

This city is located in the midst of unlimited deposits of glacial gravel. Wherever the streets are graded, gravel is exposed which is used for covering the streets, situated on the lower land. The steep grades on the streets quickly remove the water into basins, from whence it is carried by pipes out of the city.

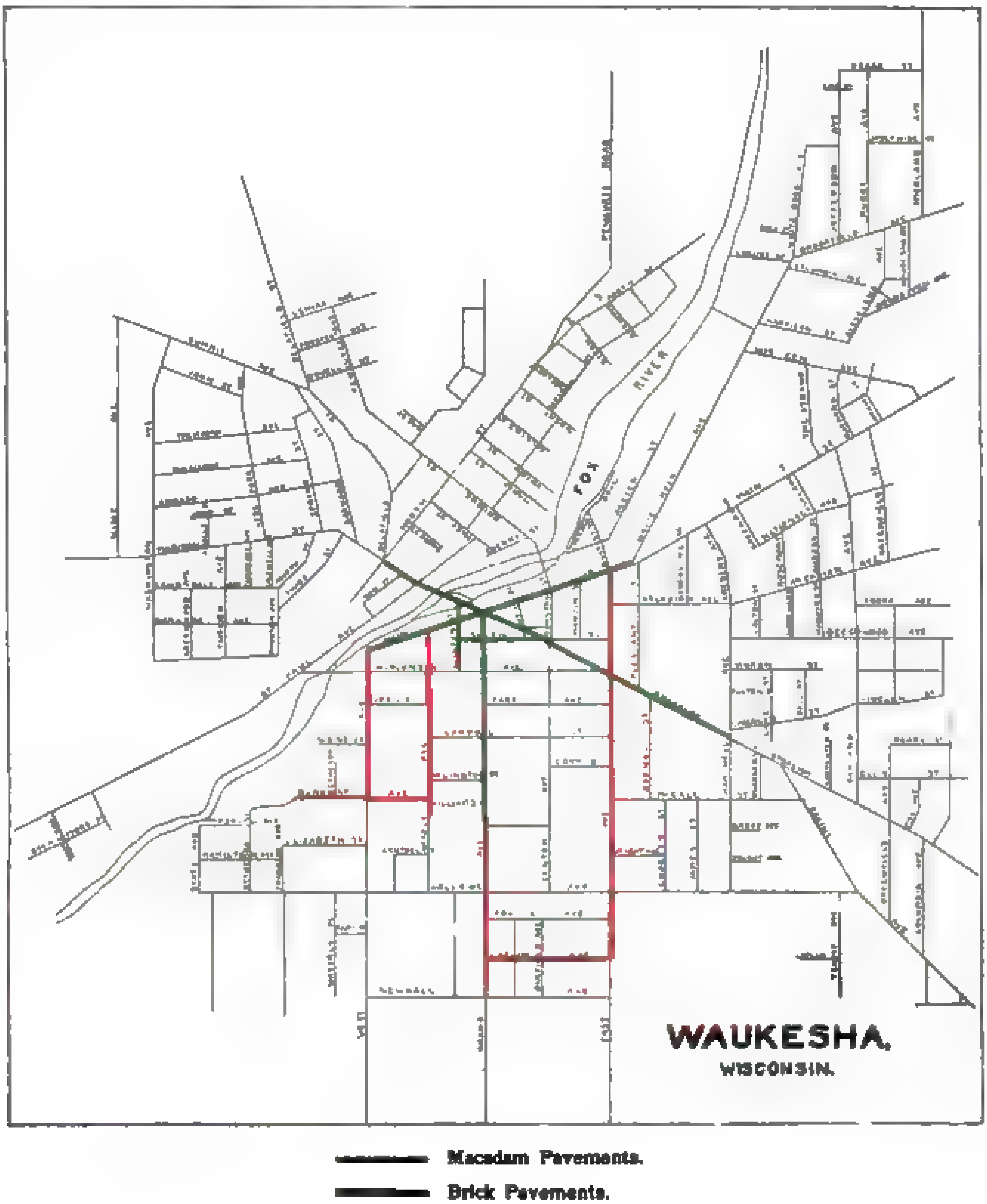
WAUKESHA COUNTY.

Waukesha county is located in the southeastern part of the state. The so-called kettle moraine extends in a northeast direction through the western part. It consists of irregular hills and valleys, necessitating steep grades along many of the roads.

The soils consist mostly of light and heavy clay loams, the latter being found mainly in the eastern part of the county.

The county is underlain mainly with limestones of the Niagara and Galena formations. The Hudson River shale outcrops in a narrow belt through the western part of the county.

The gravel and boulders of igneous rock, contained in the glacial drift, and the limestone of the Niagara and Galena formations constitute the only local materials suitable for road construction. The glacial boulders, consisting of granitic and trap rock, constitute the best material available for road metal. Used in conjunction with the Niagara limestone, they make one of the most durable and cheapest of macadam pavements.



Macadam Pavements.

Brick Pavements.

MENOMINEE FALLS.

(Pop., 687.)

This city is located near the greatest limestone quarries in the state. It may be said that the town of Menominee Falls is the heart of the crushed limestone industry.

The streets in this city have been improved for several years by the addition of crushed stone, which is spread over the surface in the same manner as it has been customary to use gravel. Although the streets have not been macadamized, it is claimed that the pavement formed by the crushed stone is very much better than the gravel which was formerly used. Three inch limestone curbing from the Lannon quarries is also used on some of the streets.

WAUKESHA.

(Pop., 7,419.)

One and one-fourth miles of brick was the total of all pavements in Waukesha up to January 1st, 1901. The first brick pavement was laid in 1897, and the last in 1900. These pavements are in first class condition and as yet have needed no repairs. The cost of cleaning is estimated at not to exceed $250 a mile per year.

The brick pavements thus far built have been mainly on business streets where the traffic is heaviest. In one or two places, however, they have been extended to residence streets, where a quieter pavement would perhaps have been more desirable.

During 1901, the city constructed 40,000 square yards of limestone macadam, at a cost of 42½ cents a square yard, not including grading or curbing. The macadam was made ten inches thick at the curb and twelve inches at the center of the street. The pavement was given a crown of one inch in three feet. The combined cement curb and gutter cost 50 cents per lineal foot. The crushed limestone was quarried in the city.

At the time the macadam pavements were being constructed, it was observed that the contractor was using

an over abundance of water when rolling. There was so much water on the pavement that the screenings and dust actually formed a thick mud, which was pushed up in front of the wheels of the roller, as they passed over the surface. This should never have been permitted as the pavement must have suffered greatly therefrom.

There is an abundant supply of granite and trap rock boulders in the vicinity of Waukesha, and there seems to be no good reason why these should not be substituted for the limestone, at least for top dressing. The correct thing for the city of Waukesha to do, is to buy trap and granite boulders from the farmers, and crush and use them for the wearing surface of the macadam. Macadam is seldom satisfactory unless stone of this kind is used. In order to insure a pavement which is clean and smooth at all times, the city should establish a system of maintenance such as is outlined in another chapter.

The following table gives such information as is available concerning the pavements already constructed.

Crushing Plants, Lannon, Wis.

Waukesha.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction: Foundation. Kind.	Foundation. Thickness.	Surface. Kind.	Surface. Thickness.	Where material was obtained.	Average width of street between curbs.	Cost of construction per sq. yd., exclusive of curb, gutter and underground pipes
Main	From W. Ave. to Pleasant St.	June, 1896	Concrete .	6 in.	Brick	4 in.	Galesburg, Ill.	41½ ft.	$1.28
Grand.......	From Broadway to Williams	June, 1897	.... do	.. do ..	.... do	.. do ..	.... do	29 ft.	1.26
Clinton......	Total length..................	June, 1899	.... do	.. do ..	.... do	.. do ..	.... do	30 ft.	1.31
South.	From Clinton to Broadway.	June, 1899.... ...	.... do	.. do ..	.... do ..	.. do ..	.... do	30 ft.	1.31
Broadway...	From River to Barstow	June, 1899........	.... do ...	.. do ..	.... do	.. do ..	.... do	44 ft.	1.31
Broadway...	From Barstow to Hartwell .	June, 1900........	.... do	.. do ..	.... do	.. do ..	Streator, Ill....	38 ft.	1.39
Madison.....	From North to River streets	June, 1899.... ...	.... do	.. do ..	.... do	.. do ..	Galesburg, Ill..	44 ft.	1.31

OCONOMOWOC.

(Pop., 2,880.)

The streets of this city have never been improved with any other material than gravel. The city has about nine miles of graded and graveled streets, which Mr. O. C. Peters, the city engineer, reports to be in good condition. Mr. Peters says that no difficulty has ever been experienced in using the gravel, and that it costs about $3,500 per year for repairing the nine miles of streets. These streets are among the better class of graveled streets in the state and yet they are much inferior to macadam pavements.

The gravel which occurs in this region consists of limestone mixed with a small percentage of clay. There is an abundance of field stone of the granite and trap rock varieties in the vicinity of Oconomowoc and it would be comparatively easy for the city to construct granite top macadam in place of the gravel.

However, if graveled streets are satisfactory to the citizens of Oconomowoc, and they are being constructed and maintained at a less expense than macadam pavements, it is doubtful if anyone would be justified in recommending a change.

WAUPACA COUNTY.

Waupaca county is located in the east central part of the state. The surface, as a whole, is rolling and hilly, necessitating short steep grades along many of the roads. The soils are mainly clayey loams except in the southwestern part, where they are replaced by sandy loams. Irregular areas of humus soils occur throughout the county.

In the western portion occur heavy deposits of drift constituting a part of the terminal moraine of the last glacial epoch.

A narrow belt of granitic rocks belonging to the pre-Cambrian formations extends north and south through the middle of the county. With the exception of this and an occasional outlier of granite, the county is underlain with sandstone of the Potsdam formation. Among the outliers is a granite mound in the southeastern part of the county, about four miles from New

1.—Crushing Plant, Western Granite Company, Devil's Lake, Wis. 2. Granite Quarry, Redgranite, Wis.

London. This granite is of excellent quality and should not be overlooked in a search for durable road metal.

The outcrops of granite and the numerous glacial boulders strewn over the surface of the county provide an inexhaustible and excellent supply of stone for road metal. The granites which occur at Waupaca and Big Falls have been crushed very extensively for macadam and manufactured into paving blocks. They are both well adapted to these purposes.

WAUPACA.

(Pop., 2,912.)

Since 1883, this city has built about three miles of granite macadam pavement. Prior to 1890, the boulders or field stone were crushed for the macadam, but in 1890 granite chips from the Bannerman paving block plant were used. Mr. Jefferson Woodworth, city clerk, informs me that the quarry chips crush easier than the boulders and make a better road.

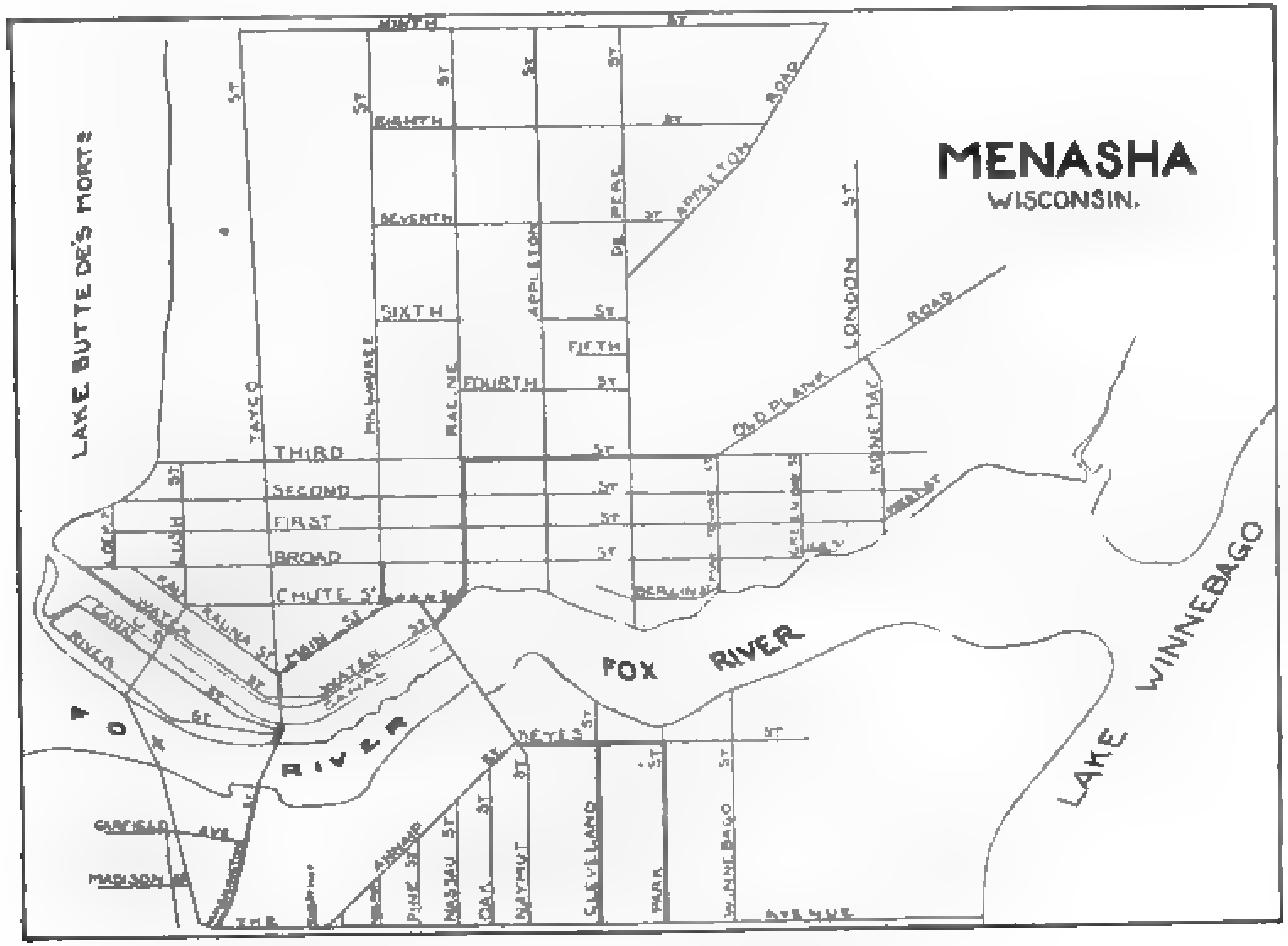
An examination of the following table shows that the macadam pavements lately constructed have a thickness of eight inches, laid in three courses. The first course of three inches consists of 1½ inch stone; the second course of three inches consists of 1 inch stones; and the third course of two inches consists of ½ inch stone. The subsoil in this city is mainly sand or loam, which makes an excellent foundation. The pavement which was laid in 1899 cost $4.75 per square rod or a little less than 16 cents per square yard. The cost of boulders delivered at the crushing plant has been $2.00 per cord of 8 tons. The city owns her own crushing plant, consisting of an Austin crusher, a boiler and an engine. The city uses a seven ton horse roller which is considered preferable to the heavier rollers in use in some cities. It costs the city annually about $100 per mile for street cleaning.

The granite macadam pavements which have been constructed in this city are among the best in the state. They demonstrate very clearly the value of this kind of pavement for the smaller Wisconsin cities. Wherever it is possible to obtain granite or trap rock, the macadam type of pavement is very desirable.

Waupaca.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction.				Where material was obtained.	Average width of street between curbs.
			Foundation.		*Surface.*			
			Kind.	Thickness.	Kind.	Thickness.		
Main*	From Granite to Badger.	1883	2 in. crushed granite	4 in.	2 in. crushed granite.	4 in.	Farmers	4 rods.
Badger	From Main to State.	1893	do	do	do	do	do	do
Fulton	From Main to High.	1896	do	do	do	do	do	do
Churchill	From Royalton to Woolen Mills.	1898	do	4 and 5 in.	Fine crushed granite.	3-4 in.	do	do
Mills	From Division to Depot.	1899	Crushed gran. 1½ in.—1 in.	6 in.	Crushed granite ¼ in. size.	2 in.	do	
Fulton	From High St. to West.	1899		8 in.			do	
Fulton†		1900			Crushed granite.	2 in.	City	22 ft.
River‡		1900			do	do	do	16 ft.

* Field stone cost $2.00 per cord of 8 tons. † Total cost of construction, $883 00. ‡ Total cost of construction, $223.00.



▪▪▪▪▪▪ Cedar Block Pavements.

▬▬▬▬ Macadam Pavements.

It is well to note, at this place, that while the macadam pavements of Waupaca are durable under the ordinary traffic of the city, they are quickly damaged by any extraordinarily heavy teaming, as shown by their condition, several years ago, after a circus parade.

WAUSHARA COUNTY.

Waushara county is located in the east central part of the state. The surface of the county is generally rolling being somewhat hilly in the western part. The soil is mainly a sandy loam. Small areas of clayey loam and humus soils occur in the eastern part and small areas of prairie loams in the western part.

This county is almost entirely within the glacial region. A triple series of hills and ridges in the western part mark the terminal moraine which passes through the county in a northeast-southwest direction. With the exception of a few small outcrops of granite in the south central part of the county, the underlying stone is altogether sandstone of the Potsdam formation.

The granitic outcrops, combined with the boulders of igneous rocks accompanying the glacial drift, constitute the principal sources of road metal in this county. The granite, which is quarried quite extensively at Redgranite, is of excellent quality both for the manufacture of macadam, paving blocks and curbing. The accompanying illustrations show one of the quarries and some of the smooth headed paving blocks manufactured at this place.

WINNEBAGO COUNTY.

Winnebago county is located in the east central part of the state bordering on Lake Winnebago. The surface of the county is generally rolling, although somewhat hilly in the western part. As a rule, the roads have light grades.

The soils are largely made up of lacustrine clays and clayey loams. Small areas of humus soils occur in different parts of the county. Prairie loams are also found in different sections.

The county is within the glaciated region, but the granitic and trap boulders are not so plentiful as in those counties in which the terminal morainal deposits occur.

The county is underlain mainly with limestones of the Galena, Trenton and Lower Magnesian formations. The underlying rock in the northwestern part of the county is sandstone of the Potsdam formation. St. Peters sandstone, also, outcrops in a thin belt extending in a north and south direction through the county.

The principal source of road metal in this county is the limestone of the Galena and Trenton formations. Wherever accessible the glacial boulders should be crushed and used in preference to the limestone.

MENASHA.

(Pop., 5,589.)

Cedar blocks and gravel have been used most extensively in this place for improving the streets. Only during the last two or three years has any attempt been made to construct macadam pavements. Data, relating to the street improvements, were not obtained but from observations it was thought that very little had been done to keep up the pavements.

NEENAH.

(Pop., 5,954.)

Most of the unpaved streets of Neenah have been improved with gravel. The subsoil in this locality is largely clay, sometimes mixed with sawdust and shavings from the saw-mills. Between 1892 and 1895 Wisconsin avenue was paved with cedar blocks. These blocks were of the usual cylindrical type and were laid on a two inch hemlock plank foundation. The space between the blocks was filled with a composition of gravel and coal tar. This pavement, which is about one mile long and 78 feet wide, cost the city 90 cents per square yard for construction.

In 1899 Cedar and Commercial streets, for a distance of 3,200 feet, were also paved with cedar block. These blocks were also laid on a two inch hemlock plank foundation and the spaces between the blocks were filled with a mixture of gravel

Cedar Block Pavements.

Macadam Pavements.

Brick Pavements.

Macadam Pavements.

Cedar Block Pavements.

and coal tar. This pavement is 45 feet wide and cost 90 cents per square yard. The cedar block pavements in this city are much better than those observed in most of the cities. However, they are very rough, in places, and unpleasant to ride over.

First street, from Wisconsin avenue through to Menasha, has been macadamized with limestone. This street has not been given sufficient crown and as a result the top is flat. The pavement also shows considerable wear on account of the heavy teaming which it is called upon to sustain.

Limestone curbing has been used on most of the improved streets. Along the macadamized streets no special gutters have been constructed.

Wisconsin avenue, from Walnut street to the Park, has been improved with broken stone. An attempt has been made to temporarily improve a number of the streets by spreading a layer of broken stone over the gravel in the middle of the streets. This has improved very greatly the condition of these streets.

This city, in company with most of the others in the state, has no system of maintenance, the streets being cleaned by the property owners. Some provision should be made by which the pavements can be kept up by the city. Unless this is done, the limestone macadam may soon be in disrepute. The quality of the pavement should also be bettered by using granite or trap rock for top-dressing.

OSHKOSH.

(Pop., 28,284.)

A major part of the pavements which have been constructed in Oshkosh are cedar block. The first of these pavements was laid in 1885 on Main and Algoma streets. In 1900 the pavement on these streets was taken up and replaced with vitrified brick. The history of cedar block pavement in Oshkosh is a repetition of the history of that pavement in all the other Wisconsin cities. It has proven unsatisfactory, and sooner or later it will be replaced with macadam, vitrified brick or some other more desirable pavement.

The following is a list of the streets which have been paved, showing the materials used and the cost of construction.

Oshkosh.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction.				Average width of street between curbs.	Cost of construction per sq. yd., exclusive of curb, gutter and underground pipes.
			Foundation.		*Surface.*			
			Kind.	Thickness.	Kind.	Thickness.		
N. Park	From Broad to Hazel	1894	Plank	2 in.	Cedar block	6 in.	32 ft.	.63
Oregon	From 13th to 17th	1894	do	do	do	do	40 ft.	.63
Mt. Vernon	From Washington to N. Park	1894	do	do	do	do	28 ft.	.63
Scott	From Jackson to Elm	1894	Stone chips	6 in.	Gravel	do	32 ft.	.20
Light	From High to Church	1894	Plank	2 in.	Cedar block	do	40 ft.	.5975
Marion	From Main to Division	1895	do	do	do	do	28 ft.	.79
Algoma	From W. Algoma to City Limits	1895	do	do	do	do	40 ft.	.6275
Court	From Washington to Ceape	1896	do	do	do	do	50 ft.	.63
13th	From Oregon to W. C. Ry	1896	do	do	do	do	40 ft.	.63
Church	From Jackson to Union	1896	do	do	do	do	40 ft.	.63
Jackson	From Irving to N. Y. Ave.	1896	do	do	do	do	36 ft.	.63
S. Main	From 13th to 16th	1896	do	do	do	do	36 ft.	.63
Wisconsin	From Prospect to N. Y. Ave	1895	Stone chips	6 in.	Crushed stone	6 in.	36 ft.	.30
Linde Ave.	From Merritt to Washington	1896	Bank gravel		Bank gravel	12 in.	30 ft.	.18
Algoma	From W. C. Ry. to Black Hawk	1889	Boards	1 in.	Cedar block	6 in.	40 ft.	1.00
Wisconsin	From Lincoln to Prospect	1891	Quarry stone	6 in.	Gravel	do	40 ft.	.283
Division	From High to Algoma	1891	Boards	1 in.	Cedar block	do	38 ft.	.75

W. Irving	From Main to Jackson	1891	Boards	1 in.	Cedar block	6 in.	40 ft.	.7375
Oregon	From Fox River to 10th	1892	do	do	do	do	40 ft.	.6875 to 6th St. .77 to 10th St.
Algoma	From Black Hawk to W. Algoma	1892	do	do	do	do	40 ft.	.6975
Washington	From Broad to Lake Winnebago	1891	do	do	do	do	34 ft.	.6975
Church	From Light to Jackson	1892	do	do	do	do	36 ft.	.90
W. Algoma	From Fox River to Algoma	1892	do	2 in.	do	do	40 ft.	.90
State	From Ceape to Washington	1893	do	do	do	do	50 ft.	.686
Waugon	From State to Broad	1893	do	do	do	do	40 ft.	.676
Otter	From State to Broad	1893	do	do	do	do	40 ft.	.676
Main	From Irving to N. Y. Ave	1893	do	do	do	do	42 ft.	.696
Jackson	From Algoma to Irving	1893	do	do	do	do	36 ft.	.676
Oregon	From 10th to 13th	1893	do	do	do	do	40 ft.	.696
Alley	From Merritt to Washington	1889	Plank	do	do	do	16 ft.	.79
High	From Main to Market	1889	Boards	1 in.	do	do	40 ft.	.97
Main	From Fox river to N. L. of Church street.	1885	do	do	do	do	56 ft.	1.135
Algoma	From Main to W. C. Ry	1885	do	do	do	do	34 ft.	1.075
High	From Market to Light	1890	do	do	do	do	40 ft.	.825
S. Main	From Fox River to 13th	1890	do	do	do	do	40 ft.	.895
Main	From Church to Irving	1890	do	do	do	do	42 ft.	.90
Ceape	From Main to Broad	1890	do	do	do	do	40 ft.	.89
Otter	From Main to State	1888	do	do	do	do	40 ft.	.90
Waugon	From Main to State	1887	do	do	do	do	40 ft.	.93
Washington	From Main to State	1887	do	do	do	do	32 ft.	.93
Washington	From State to Broad	1889	do	do	do	do	32 ft.	.90

Oshkosh—Continued.

Name of street.	Part paved, macadamized, etc.	Date.	Materials Used in Construction.				Average width of street between curbs.	Cost of construction per sq. yd., exclusive of curb, gutter and underground pipes.
			Foundation.		*Surface.*			
			Kind.	Thickness.	Kind.	Thickness.		
Merritt	From Main to Broad	1888	Boards.	1 in.	Cedar block	6 in.	30 and 26 ft.	.90
Church	From Main to Division	1888	do	do	do	do	36 ft.	.90
Merritt	From Broad to Hazel	1890	do	do	do	do	26 ft.	.83
Rosalin	From Ceape to Washington	1897	Telford	6 in.	Crushed stone	do		.40
New York	From High to Elm	1897	do	do	do	do		.40
Wisconsin	From Pearl to Marion	1899	do	do	Macadam	do		.39
New York	From Elm to Jackson	1898	do	do	do	do		.3775
Merritt	From Hazel to Lake Drive	1898	do	do	do	do		.3675
Pleasant	From Merritt to Hudson	1898	do	do	do	do		.39
Mt. Vernon	From Irving to N. Park	1898	do	do	do	do		.425
Pearl	From Main to Division	1898	Field stone	do	do	do		.335
Ceape	From Broad to Bowen	1898	do	do	do	do		.3775
West Algoma	From Fox river to City Limits	1899	do	8 in.	Crushed "Hard heads."	4 in.		.43
Scott	From Main to Jackson	1898	Telford	6 in.	Macadam	6 in.		.38
Algoma	From Main to Bond	1900	Concrete	do	Brick			1.93
Main	From Fox river to W. L. of Polk street.	1900	do	do	Vitrified brick			1.86
Ohio	From 9th to 13th	1894	Common macadam.		Common macadam.			

Wright	From Irving to Scott	1893	Gravel	1 ft. deep.	Gravel			
McKane	From High to Algoma	1892	do	6 in.	Stone chips	6 in.		
Main	From N. Y. to City Limits	1892	do	do	do	do		
Irving.[1]	From Bower to Hazel	1894	Common macadam.	do				
Olive	From 4th to 9th	1893	do	do				.62 sq. yd.

The information contained in the above table was obtained through the courtesy of Mr. George H. Randall, city engineer.

July 16th, 1901, a careful examination was made of the cedar block, macadam and brick pavements, noting defects in materials and construction. State street was paved in 1893 with cedar blocks laid on a foundation of one inch boards. This street is badly in need of repairs, especially next to the curbing, where the pawing of the horses had broken and loosened the blocks. The cedar block pavement on Court street, from Ceape to Washington avenue, which was constructed in 1896, is in good condition. The cement curb and gutter which lines both sides of the street assist greatly in the removal of the surface water. In this case the curb and gutter had been made separately and between the two there was considerable of an opening through which a portion of the surface water must find its way into the subsoil underneath. In 1889, Merrill street, between Hazel and Main streets, was paved with Cedar block. The blocks were laid on a foundation of one inch boards, previously covered with tar. The joints between the blocks were thoroughly filled with a mixture of tar, gravel and sand. This pavement, although on a residence street and specially prepared, is one of the poorest in Oshkosh today. For three years it has been in an impassable condition. Algoma street was paved in 1891 and 1893 with cedar blocks and is today in very poor condition. That part of the pavement which was laid in 1891 is worn out and must soon be replaced by another pavement.

In 1897 Rosalia street, between Ceape and Washington streets, was paved with limestone macadam at a cost of 41 cents per square yard. Curbing cost 24½ cents per running foot, additional. This street is in very good condition. Merritt street, between Hazel and Lake, was paved with limestone macadam in 1898. The foundation of this street was built out of granite and trap rock boulders. The surface consists of four inches of medium sized crushed limestone and two inches of screenings. The bare pavement cost 43 cents per square yard, and the limestone curbing 24½ cents per running foot. In

Cedar Block Pavement, Showing Removal of Street Car Tracks. Algoma Street, Oshkosh, Wis.

New Limestone Macadam Pavement. Pleasant Avenue, between Merrit and Hudson Streets, Oshkosh, Wis.

1898 Pleasant avenue, between Merritt and Hudson streets, was paved with limestone macadam. Here again granite and trap rock were used for the foundation, and limestone for the surface. The macadam on this street cost 40 cents per square yard and the curbing 24½ cents a running foot. This street is in excellent condition and the pavement is one of the finest in the city.

East Irving street, between Main and Lake streets, was graveled in 1887, and is in very good condition today. This is one of the best constructed gravel streets in the state.

The brick pavement on Algoma street, between the Wisconsin Central railroad tracks and Main street, was laid on a concrete foundation and the joints were filled with cement grout, made of Atlas cement and sand in the proportion of one to one. The brick pavement on Main street was laid two months later than that on Algoma street, sand being substituted for cement grouting. The brick on Algoma sreet show very little deterioration, while those on Main street are badly chipped. There is very little difference in the amount or character of the traffic on these two streets, at least not sufficient to account for the difference in wear. This must be largely attributed to the different way in which the joints were filled. The difference in the wear of these two pavements is nicely shown in the accompanying illustrations.

Oshkosh, like most of the other Wisconsin cities, has no system of maintenance. If it is the purpose of the city to construct macadam pavements on the streets throughout the residence districts, it will be necessary to provide a system of maintenance by which these pavements can be constantly kept up.

It appears to me that a mistake has been made in not using the field stone or "nigger heads," as they are called, for top dressing instead of for the foundation. The durability of the macadam would be very greatly increased if the granite and trap rock were crushed and used on the surface. The limestone is equally as satisfactory for the foundation. The limestone used in this city is obtained from the Trenton formation. It is a dense, hard, bluish gray stone and is considered one of the best limestones for macadam that is quarried in the state.

WINNECONNE.

(Pop., 1,042.)

The streets of this village are improved by the addition of gravel which is obtained from a pit about three miles from town. The subsoil is a clay loam. Curbing is only used in places. The streets are crowned with a grader and the gravel spread on the top to a thickness of several inches.

The worn out gravel dust on the business part of Main street was removed in 1902 and it was found that the gravel had become cemented together in a hard, compact mass resembling macadam.

WOOD COUNTY.

Wood county is located in the central part of the state. The surface is mainly rolling, although broken in places by ridges and hills. The soils are mainly sand and sandy loams, except in the northern part where clayey loams occur. A large area of humus soil is found in the southern part of the county. Other smaller areas also occur in the northeastern part. The north half of the county is covered with a thin mantle of drift deposited by the earlier ice sheets.

The underlying rock, in the southern and western parts, is mainly sandstone of the Potsdam formation. In the north and northeastern portions the underlying rocks are of the granitic and gneissoid varieties. The granitic rocks are also found outcropping along the river almost to the south line of the county. Several isolated outliers of granite rocks also outcrop in the western part of the county.

The outcrops of granitic rocks, combined with the glacial field stone, which is scattered quite abundantly over the northern part of the county, constitute an inexhaustible supply of materials for road metal.

Brick Pavement Cement Grouting Filling Joints. Algoma Street, between Main Street and the Wisconsin Central Railway Tracks, Oshkosh, Wis.

Brick Pavement Joints Filled with Sand Main Street, Oshkosh, Wis.

GREATER GRAND RAPIDS.

(Pop., 4,493.)

Grand Rapids has up to date about 1½ miles of granite macadam pavement. The first street paved was finished in 1897 and the last in 1900. All of the macadam is in excellent condition. These pavements are without question among the best of their kind in Wisconsin. The pavement is in some places unnecessarily. wide. For example, Cranberry street has a width of 42 feet of macadam. This unnecessary width increases both the cost of construction and cost of maintenance. The pavement is also unnecessarily thick. A thickness of seven inches, except on business streets and where the subsoil is soft, is all that is necessary.

The city purchases boulders of granite and trap rock from the farmers, paying $2.25 per cord, delivered at the crusher. The total cost of the macadam pavements thus far constructed has been from 45 to 50 cents per square yard.

There is an abundance of excellent trap rock and granite, both in the form of boulders and as ledges of rock, in close proximity to this city. The boulders or field stone are purchased from the farmer, because they are thought to be less expensive than the quarry stone.

All of the street improvements which have thus far been made are on the east side of the river. The streets on the west side need to be improved and with the great abundance of excellent and inexpensive material, they should be macadamized at an early date.

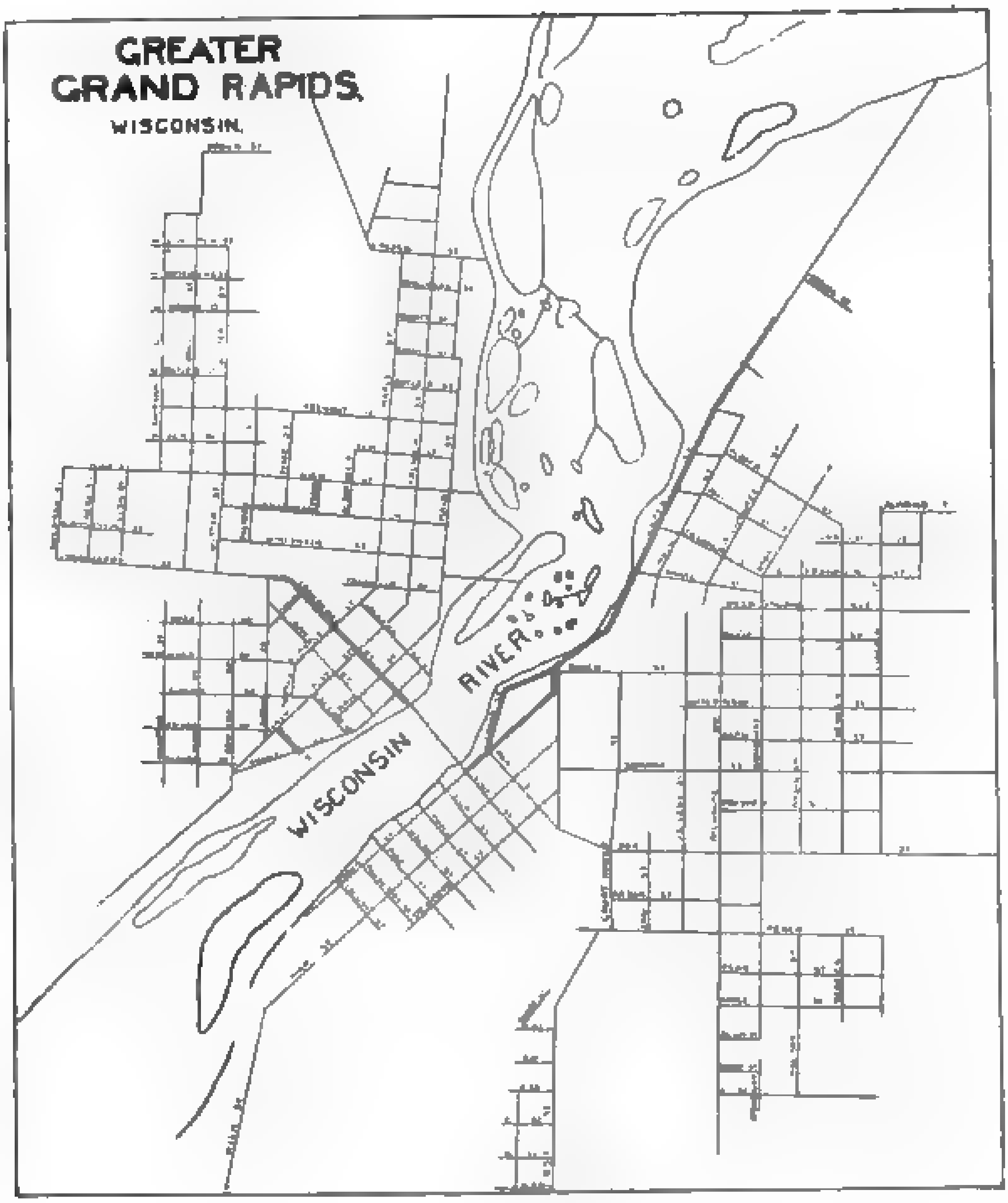
Limestone curbing has been used along the paved streets. No special gutters have been constructed to carry off the surface water, and were one prone to criticize it would be in this direction. Especially next to the curbing, where horses are allowed to stand, there should be a three foot gutter of stone, brick or concrete. Along all streets gutters are a very essential construction.

MARSHFIELD.

(Pop., 5,240.)

Two blocks of Central avenue have been macadamized, one in 1895 and one in 1898. Field stone, purchased from the farmers, is used for making the crushed stone. In constructing the pavement, the larger sizes of crushed stone are laid on the bottom to a thickness of five inches, constituting the foundation course. Above this is laid a second course, having a thickness of three inches, and a third having a thickness of two inches, making a total thickness of ten inches when rolled. Central avenue is the business street of the city and has a width of 76 feet between the curbs, all of which has been macadamized. The total cost of constructing the two blocks of this pavement was $4,413.33.

The pavement is in excellent condition and thus far has required no repairs. The road is smooth and hard and no difficulty has been experienced in the use of the granite and trap rock of which the field stone is composed. Attention might be called to the advantage of having wide concrete, stone or brick gutters, not only to remove quickly the storm water, but to withstand better the stamping of the horses that may be hitched along the curb.



Granite Macadam Pavements.

Granite Macadam Pavement. A business street, Grand Rapids, Wis.

CHAPTER VI.

ABRASION AND CEMENTATION TESTS.

The experiments described in this paper were performed by Mr. Norman Curtis under the direction and supervision of the writer.

The object of the tests was to obtain the comparative wearing and cementing values of the different road metals used in Wisconsin.

Requests for samples were sent to all of the quarries that were furnishing stone for macadam purposes and also to cities using crushed stone. The tests were made precisely similar to those made by the Massachusetts Highway Commission and the Maryland Geological Survey. A special effort was made to have the conditions uniform, and to follow closely the conditions prescribed by the Massachusetts Highway Commission, which was the first in the United States to adopt these tests, and whose methods have been taken as the standard wherever such tests have been made in this country. By following this method results were obtained which were not only comparable with one another, but also comparable with tests made elsewhere.

The abrasion test seeks to imitate as closely as possible the natural force which wears the street pavement. The machine which is used for making the abrasion tests was the result of nearly a century of investigation of road materials by the French government. It is called the Duval Abrading machine and is named after its inventor, a French engineer. "It was first exhibited at the French Exposition in 1878 and was immedi-

ately adopted as the best method of determining beforehand the relative wearing powers of rocks. By its use a large number of tests have been made of the various rocks used on the French roads, and the results are in very satisfactory accordance with the results obtained by many years study of the roads themselves."*

"The abrasion machine consists of four cylinders, each 20 c. m. in diameter and 34 c. m. in depth. Each of these cylinders is closed at one end and has a tightly fitting cover for the other. They are fastened to a shaft so that the axis of each cylinder is at an angle of 30° with the axis of rotation of the shaft. The shaft which holds the cylinders is supported by bearings, and at one of its ends is a pulley by which the cylinders are revolved, at the other a revolution counter."**

The crushed stone used for these tests was taken from samples of road metal received for this purpose. No stone was used whose greatest dimension was more than two and one-half inches, or less than two inches. Five kilograms of the stones were weighed out and the three dimensions of ten pieces taken at random were obtained. Each dimension given in the table, corresponding to any sample, is the mean of ten measurements taken in the manner described. The sample weighed out was then placed in one of the cylinders and the cover bolted on. When a sample had been placed in each of the cylinders they were revolved at the rate of about 2,000 revolutions per hour until they had been given 10,000 revolutions.

The content of each of the cylinders was removed, the cylinder being carefully brushed out to save all of the dust which was worn off. The detritus which would pass through a sieve having 16 meshes to the inch was then separated from the coarser material and weighed, the dust being removed from the stones by careful brushing. The percentage of the original weight of the stones, which went through the 1-16 inch sieve, is the percentage of wear as recorded in the table. The coefficient of

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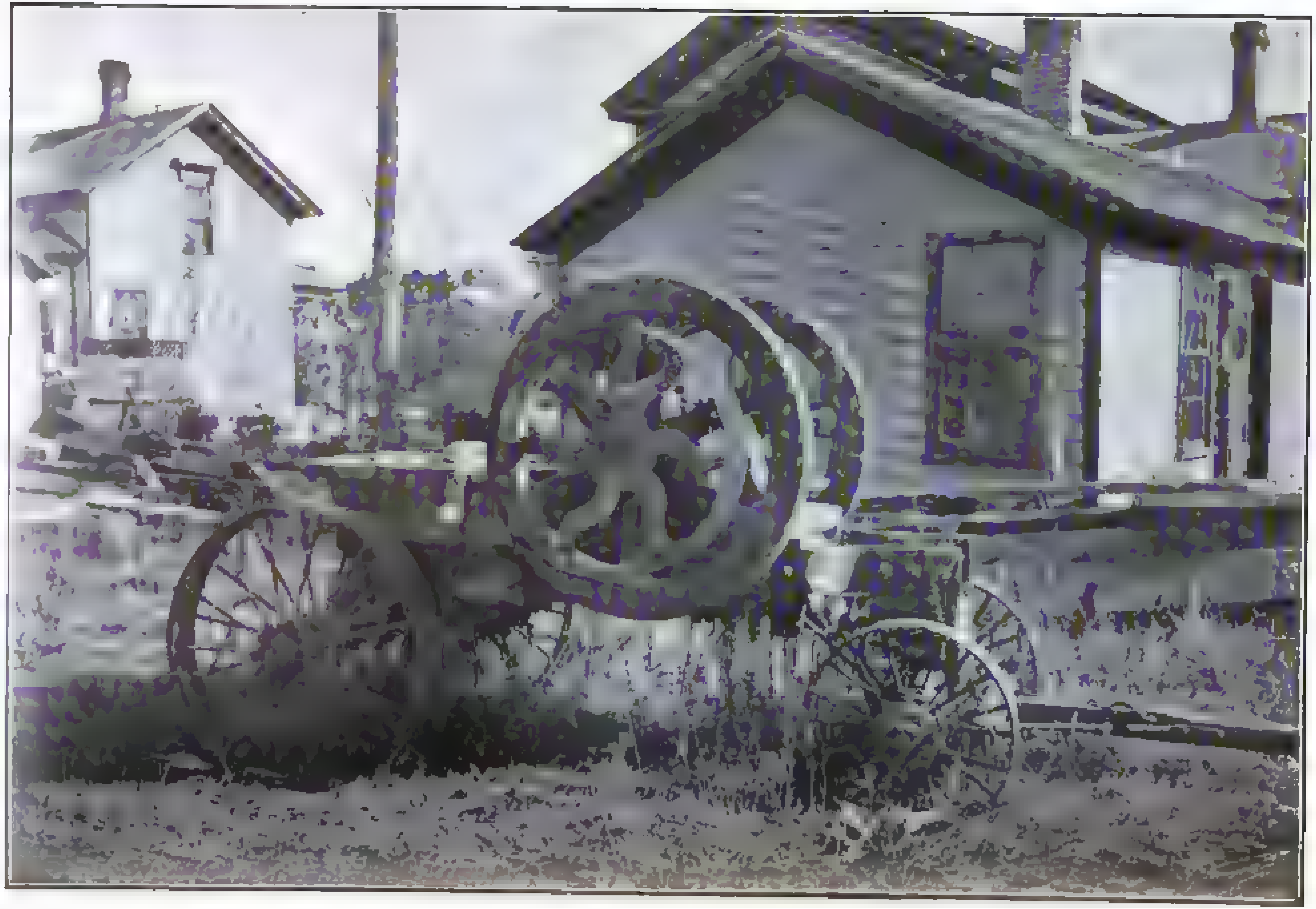
*1899 Rept. Md. Geol. Survey, Vol. III, pp. 320.

**Annual Rept. Mass. Highway Com. pp 59.



Portable Rock Crusher, Greater Grand Rapids, Wis.

wear given in the table is the rather arbitrary coefficient adopted by The National School of Roads and Bridges of France. It is expressed by the formula—

$$\text{Coefficient of wear} = \frac{400}{w}$$

where "w" is the weight in grams of the dust which passes through a sixteenth-inch mesh sieve. The dust was then tested to determine its fineness by passing such portion of it as would go through a sieve having 10 meshes to the inch.

Two abrasion tests were made on each sample, in the manner described, the second being denoted by the suffix "a."

The cementing power of the dust worn from a pavement by traffic is one of the most important properties of a stone used for macadam. The Massachusetts Highway Commission, after experimenting for five years to determine a suitable means of testing this property, finally adopted the Page impact test for dust briquettes. The dust which passes the 100 mesh sieve is mixed with a small amount of distilled water and moulded into a cylindrical briquette, having a cross-section of 25 mm. and a height of 25 mm. In moulding these briquettes they are subjected to a pressure of 100 k. g. per sq. cm. for one minute, after which they are taken from the mould and thoroughly dried before testing in the impact machine.

The machine for testing these briquettes consists of a hammer, weighing 1 k. g., which is raised by means of a screw and dropped automatically when it has reached the desired height. The hammer falls on a plunger which rests on the briquette to be tested. An automatic record of the distortion of the specimen, and of the number of blows is made on a piece of metallic faced paper fastened to a drum, which moves through a small angle after each blow of the hammer. The record is made by a pointer so attached to the plunger that its vertical motion is six times that of the plunger.

The fall used was one cm. and the cementation value is given by the number of blows required to break the briquette.

Report of Abrading Tests on Crushed Rocks.

Number of sample.	Name of sender.	Date of beginning of test.	Hours.	Total number of revolutions.	Number of revolutions per hour.	Dry weight of stone before testing.	Dry weight of stone after testing.	Loss in weight.	Percentage of wear.	Coefficient of wear.	Rank.	Kind of stone.	Sizes of pieces of stone.	Weight of 100 mesh dust.
			hr. min.			Grams.	Grams.	Grams.	Pr ct.				Inches.	Grams.
1..	Montello Granite Co.	June, 1900.	4 3	10,000	2,460	5,000	4,892	108	2.16	3.7	3	Granite	1.9x1.35x.9	107½
1a.	Montello Granite Co.	.. do ..	4 38	10,000+	2,160	5,000	4,887	113	2.26	3.54	....	Granite	2.15x1.4x0.85	112
2..	Wisconsin Gran. Co.	.. do ..	4 3	10,000	2,460	5,000	4,825	175	3.50	2.28	8	Quartzite	2.25x1.9x1.4	174
2a.	Wisconsin Gran. Co.	.. do ..	5 0	10,000	2,000	5,000	4,852	148	2.96	2.70	....	Quattzite	2.2x1.8x1.0	147
3..	F. Powell, La Crosse.	.. do ..	4 8	10,000	2,460	5,000	4,507	493	9.86	0.81	16	Limestone ...	2.3x1.8x1.45	492
3a.	F. Powell, La Crosse.	.. do ..	3 59	10,000	2,500	5,000	4,489	511	10.22	0.78	....	Limestone ...	2.1x1.6x1.2	510
4..	Horlick's L. & S. Co., Racine.	.. do ..	4 3	10,000	2,460	5,000	4,649	351	7.02	1.14	15	Limestone ...	2.15x2x1.4	350
4a.	Horlick's L. & S. Co, Racine.	.. do ..	3 59	10,000	2,500	5,000	4,653	347	6.95	1.15	....	Limestone ...	2.25x1.75x1.2	339
5..	G. H. Chaffee, Sparta	.. do ..	4 38	10,000+	2,160	5,000	4,895	105	2.10	3.81	2	Flint	2.2x1.68x1.8	103
5a.	G. H. Chaffee, Sparta.	.. do ..	5 0	10,000	2,000	5,000	4,894	106	2.12	3.77	....	Flint	2.2x1.65x1.2	104
6..	Richwood crushed S. Co., Watertown.	.. do ..	4 38	10,000+	2,160	5,000	4,805	195	3.90	2.06	12	Limestone. ..	2.25x1.7x1 0	194
6a.	Richwood crushed S. Co., Watertown.	.. do ..	5 0	10,000	2,000	5,000	4,795	205	4.10	1.95	....	Limestone ...	2.25x1.8x1.25	195
8..	Waupaca crushed Gran. and S. Co.	. do ..	4 33	10,000+	2,160	5,000	4,910	90	1.80	4.44	1	Granite	2.05x1.4x8.5	89
8a.	Waupaca crushed Gran. and S. Co.	.. do ..	5 0	10,000	2,000	5,000	4,918	82	1.64	4.88	....	Granite	2.05x1.3x.75	81
9..	Sheboygan Lime Wks.	.. do ..	4 50	10,000	2,070	5,000	4,677	323	6.46	1.24	14	Limestone ...	2.25x1.75x1.2	322
9a.	Sheboygan Lime Wks.	.. do ..	5 0	10,000	2,000	5,000	4,665	335	6.70	1.19	....	Limestone ...	2.3x1.7x1.25	333
10..	M. Maxon, Waukesha	.. do ..	4 50	10,000	2,070	5,000	4,855	145	2.90	2.76	6	Trap.	2.3x1.7x1.0	143
10a.	M. Maxon, Waukesha	.. do ..	5 0	10,000	2,000	5,000	3,868	132	2.64	3.03	....	Trap.	2.2x1.7x0.9	131

11..	C. F. Smith, Appleton	.. do ..	4	50	10,000	2,070	5,000	4,827	173	3.46	2.33	9	Limestone. ..	2.25x1.6x1.05	172
11a.	C. F. Smith, Appleton	.. do ..	5	00	10,000	2,000	5,000	4,812	188	3.76	2.13	....	Limestone. ..	2.25x1.5x1.05	183
12..	Menon-Falls-Lannon S. Co., Lannon, Wis.	.. do ..	4	50	10,000	2,070	5,000	4,798	202	4.04	1.98	13	Limestone. ..	2.15x2.0x1.1	201
12a.	Menon-Falls-Lannon S Co., Lannon, Wis	.. do ..	3	59	10,000	2,500	5,000	4,800	200	4.00	2.00	....	Limestone. ..	2.28x1.67x1.2	195
13..	Marblehead Lime Co.	.. do ..	5	00	10,000	2,000	5,000	4,805	195	3.90	2.05	11	Limestone. ..	2.1x1.63x1.1	194
13a.	Marblehead Lime Co.	.. do ..	3	59	10,000	2,500	5,000	5,807	193	3.86	2.07	....	Limestone.	2.1x1.55x1.05	192
14..	Sheboygan L. & S. Co.	July, 1900.	3	58	10,000	2,520	5,012	4,818	194	3.88	2.06	10	Field stone ..	2.25x1.9x1.5	192
14a.	Sheboygan L. & S. Co	.. do ..	3	58	10,000	2,520	4,993	4,812	181	3.62	2.21	....	Field stone ..	2.35x2.17x1.37	180
15..	Rico Lake	Dec., 1900.	4	41	10,000	2,110	5,000	4,882	118	2.36	3.39	7	Quartzite	2.15x1.7x1.2	117
15a.	Rice Lake	.. do ..	4	40	10,000	2,140	5,000	4,835	135	2.70	2.93	....	Quartzite	2.2x1.8x1.2	134
16	Utley.	.. do ..	4	41	10,000	2,110	5,000	4,848	152	3.04	2.63	4	Rhyolite. ...	2.3x1.85x1.25	150
16a.	Utley.	.. do .	4	40	10,000	2,140	5,000	4,838	162	3.24	2.47	....	Rhyolite. ...	2.3x1.9x0.8	161
17..	Berlin	.. do ..	4	41	10,000	2,110	5,000	4,862	138	2.76	2.90	5	Rhyolite.	2.25x1.75x1.4	137
17a.	Berlin	.. do ..	4	40	10,000	2,140	5,000	4,817	153	3.06	2.61	....	Rhyolite.	2.4x1.8x1.3	152

Cementation value — Impact test — First series.

Kind of stone.	Granite.	Quartzite.	Lime S.	Lime S.	Flint.	Lime S.	Granite.	Lime S.	Trap.	Lime S.	Lime S.	Lime S.	Field S.	Quartzite.	Rhyolite.	Rhyolite.
No. of sample.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
No. of blows.....	16	19	8	48	67	23	64	5	2	15	12	7	9	36	6	7
	13	13	7	58	[illegible]	19	21	16	2	60	10	8	15	16	12	32
	....	15	7	18	57	11	15	21	4	41	7	11	10	17	8	10
	....	11	13	13	56	18	24	6	4	12	....	14	15	50	8	10
	....	....	10	37	19	21	...	10	8	23	....	4	31	30	8	17
	....	...	8	87	...	9	....	...	9	27	....	3	12	39	6	15
	....	...	8	76	...	13	...	..	6	15	....	8	11	31	6	23
	....	...	6	16	...	15	...	.	15	15	...	13	11	13	15	16
	...	..	6	33	...	32	....		...	63	..	..	19	....	7	10
	....	....	8	31	...	23	...	...		...	...	....	73	....	8	....
	....	....	...	21	...	10	....	.	..	....	...	...	18	....	9	....
	....	....	...	28	...	8	...	....	...	....	.	....	15	....	....	....
	...	...	...	27	....	10	...	....	...	....	..	....	....	...	....	...
	...	.	...	37	...	27		....	.	....	....	...	...	....	....	....
	..	...	....	..	...	8		....	.	...	.	....	....	...	....	....
Average.	14	14	9	38	47	18	15	12	6	30	10	8	18	20	8	16

Duval Abrading Machine. Wisconsin Geol. and Nat. Hist. Survey Laboratory.

Page Impact Machine and Balances. Wisconsin Geol. and Nat. Hist. Survey Laboratory.

Cementation value — Impact test — Second series.

Kind of stone.	Granite.	Quartzite.	Lime S.	Lime S.	Flint.	Lime S.	Granite.	Lime S	Trap.	Lime S.	Lime S.	Lime S.	Field S.	Quartzite.	Rhyolite.	Rhyolite.
No. of sample.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
No. of blows.....	36	....	19	....	....	35	....	24	....	38	....	34	....	....	....	....
	51	....	12	....	....	32	....	46	....	39	....	15	....	....	....	....
	40	....	15	....	....	41	....	49	....	51	....	26	....	....	....	....
	....	....	17	....	....	25	....	45	....	....	....	12	....	....	....	....
	....	....	15	....	....	....	....	35	....	....	....	25	....	....	....	....
	....	....	12	....	....	....	....	31	....	....	....	24	....	....	....	....
	....	....	11	....	....	....	....	51	....	....	....	....	....	....	....	....
	....	....	11	....	....	....	....	35	....	....	....	....	....	....	....	....
	....	....	12	....	....	....	....	51	....	....	....	....	....	....	....	....
	....	....	12	....	....	....	....	30	....	....	....	....	....	....	....	....
	....	....	....	....	....	....	....	20	....	....	....	....	....	....	....	....
Average......	42	..	14	....	....	33	....	39	....	36	....	23	....	....	....	....

DISCUSSION OF TABLES.

The abrasion tests were very satisfactory. Not only did the different tests of the same sample agree with one another, but the tests of the various samples of the same class of stone showed a very satisfactory agreement; and the writer believes that the results obtained in this test give a very reliable estimate of the wearing properties of the stone when used in a pavement.

The results obtained from the impact test were not so satisfactory. The results were no more erratic than those obtained elsewhere with the machine and it seems as though the same criticism might be made on the results obtained elsewhere. All results obtained in making the tests for this report, which were abnormal or in any way suspicious, were discarded. A second series of tests was made for some of the samples with little or no improvement in the results obtained. These tests were made in the manner prescribed by Mr. L. W. Page, geologist of the Massachusetts Highway Commission, and inventor of the impact machine.

The results are given, not as being of any value in determining the cementing power of the materials tested, but rather to show the weakness of attempting to draw any conclusions from tests made in this manner.

It was suggested by the late Prof. J. B. Johnson that satisfactory results might be obtained if a thin layer of plaster of paris were inserted above and below the briquette to insure an even bearing, and a better distribution of pressure. The writer regrets that lack of time prevented further experiments along this line. It is to be hoped that some one will take up this matter and demonstrate positively whether or not the Page impact machine can be used with any degree of reliability in determining the cementing capacity of broken stone.*

*Since writing this, announcement has been made that the Page impact machine and the manner of making briquettes have been improved by Mr. A. N. Johnson of the Maryland Geological Survey, so that reliable determinations of the cementing properties of crushed stone can be obtained.

A Macadam Pavement with Plank Curb, Showing the Usual Style of Steam Roller.

CHAPTER VII.

MISCELLANEOUS CONSIDERATIONS.

THE RELATIONS OF THE PAVEMENT TO THE AGE AND USEFULNESS OF HORSES AND VEHICLES.

During the preparation of this report, an investigation of the effects of different kinds of pavements on horses and vehicles, used by transfer companies, wholesale houses, livery stables, etc., in the larger cities of the United States, was begun but not completed.

To ascertain the extent and character of the injuries sustained by horses when driven over the different pavements correspondence was entered into with the above firms and with prominent veterinary surgeons in many of the larger cities of the United States.

From the replies received, with one exception, it appears that more injuries to horses are attributable to asphalt than to any other of the common pavements. Dr. S. W. Mount of Milwaukee, says that there are more fractures from falling on asphalt, in winter, than all other accidents. He also observes that during the summer the heat absorbed by this pavement makes it so hot as to dry the hoofs, causing contraction and subsequent fever, pain and lameness. These observations are corroborated by other veterinary surgeons in different parts of the country.

The general foreman of the New York Transfer Company which works 650 horses in the city of New York says, "We have found asphalt pavement to be the hardest on the horses.

In summer it is soft and the wheels sink into it and the horse has much harder work. In the winter it is smooth and slippery and the horse can have no foot hold. Any other pavement is better than asphalt."

On the other hand Dr. Wm. Shields of Philadelphia says that asphalt prolongs the life of a horse provided he is first shod with a rubber pad in front to keep him from slipping and to take the jar from the tendons and shoulders.

From the replies received, it appears that all block pavements,—stone, brick or wood,—when they become worn on the edges give an uneven footing causing the animals to throw their weight on one side. This is said to result in injury to the bones, muscles and tendons of the legs. Stone block is said to cause sprains of all the propelling muscles and is a cause of all diseases peculiar to the foot.

From the standpoint of the man who drives the horse, properly constructed macadam pavements are most desirable. The correspondents were almost unanimous in declaring that "macadam is the only road for the horse."

The returns, which were received, indicate that the different pavements, as regards the number of years that a horse is servicable, will rank about as follows:

(1) Macadam, (2) wooden block, (3) brick, (4) stone block and (5) asphalt.

Driving horses and horses used for light and heavy delivery when driven over asphalt or block pavements will lose from five to ten years of their servicable life, according to the individual horse and the character of the work.

From such data as were collected it appears that for rapid haulage and size of load,—the year around,—macadam is preferable to all other pavements. The order in which the other pavements should follow is doubtful and the data which are at hand do not assist in the solution. The loads carried on the different pavements depend on many factors and vary from 1,000 to 4,000 pounds per horse. The rate of travel varies from three to eight miles an hour, depending upon the grade, character of pavement, kind of horses and load.

Macadam Pavement in Process of Construction. Michigan Avenue, Sheboygan, Wis.

In the matter of vehicles the improvements have kept pace with the changes in the construction of the pavements and the demands of travel. Rubber tires are said to have lessened the repair bills to all vehicles fifty per cent.

With respect to the serviceability of vehicles it appears that the pavements will rank about as follows:

(1) Asphalt, (2) macadam, (3) wooden block, (4) brick and (5) stone.

The information at hand shows that the period of serviceability of a vehicle driven over city pavements ranges from three to twenty years, averaging from nine to ten years under the most favorable conditions. The repairs necessary during this period result largely from injuries sustained while being drawn over granite block pavements. Injuries on sheet pavements result very largely from turning out of the street car tracks and are not due to the character of the pavement.

The effect, which the different pavements have on the life of vehicles and horses, has been given very little attention in the consideration of the different pavements. Horses and wagons have been looked upon as agents of destruction, against which a strong and unyielding pavement must be built.

But we must not forget that, where there is action, there must be re-action. Those who buy vehicles and horses know that they must be strong in proportion as the pavement is rough, hard and unyielding. It is a matter of history that the introduction of certain kinds of pavement has compelled the use of vehicles especially constructed to withstand the jolting and pounding which the pavement incurs. Such vehicles cost more and wear out sooner than those used on smooth, elastic pavements. On the other hand horses often sustain injuries which render them useless after a few years service in some of the larger cities.

A railroad company levels its roadbed and straightens the track, not so much to increase the speed of its trains, as to reduce the cost of maintaining the track and rolling stock. In fact the most important problem confronting the railroad engineer is to minimize the cost of maintaining the roadbed

and rolling stock. The same problem confronts the city engineer,—the reduction to a minimum of the cost of maintenance of the rolling stock and pavement.

THE PASSENGER AND THE PAVEMENT.

The cleaner and smoother the pavement the more agreeable it is to ride over. A pavement, which is constantly jolting and jarring the vehicle in which one is riding, can not be considered agreeable. One would scarcely think of riding over a stone block pavement for pleasure. At least not such a block pavement as we are familiar with on the business streets of Milwaukee and Chicago. Neither would one choose a partly worn out cedar block pavement for this purpose. The sheet pavements, asphalt, macadam and tar macadam, and the newly constructed brick and modern wooden block pavements are the most pleasant of any to drive over.

The fine dust, which accumulates more or less on all of these pavements, makes driving very disagreeable when the wind blows. Limestone macadam is especially disagreeable in this respect, unless constantly sprinkled and cleaned. If the limestone macadam dust is permitted to accumulate on the pavement, it will form a sticky mud duing wet weather or when the streets are flushed with water after sprinkling. This mud not only makes driving unpleasant but it also ruins the varnish and paint on the vehicles. With granite macadam, asphalt, brick or modern wooden block there is very little danger from mud, provided the pavements are given ordinary care.

In the construction of pleasure drives the agreeableness of the pavement to the driving public is a chief consideration.

THE RESIDENT AND THE PAVEMENT.

The person who resides on a street which is about to be paved usually desires a pavement which is clean and noiseless. Looking at the problem from this point of view, one would first need to consider the manner in which the city maintains her streets

Crushing Plant, with Quartzite Hills in Background, Ablemans, Wis.

in general and the character of the traffic which it is expected will use the thoroughfare.

Among the pavements considered, macadam and wooden block are the least noisy, while brick, wooden block and asphalt are the cleanest. The red dust which results from the disintegration of a poor brick pavement is very objectionable. However, a good brick pavement, if well cleaned, is usually less dusty than asphalt.

It is difficult to select a pavement which will satisfy all the varied interests. First and most important is to secure a pavement that, while adapted to the kind of traffic will in the long run be the cheapest for the tax payers. The tax payer, the teamster, the pleasure driver, the horses and vehicles and the residents all have an interest in the kind of pavement constructed. The city cannot satisfy all of these varied interests but should seek to provide a pavement for the majority and not the minority. The city should build pavements which are best suited to the conditions irrespective of the desire of a few monied men whose interests would be better conserved by a different kind of construction.

The time is near at hand, when, in the construction of a pavement, the interest of the user must be considered with that of the tax payer and the builder. When that time comes, we shall build cleaner, quieter and more beautiful pavements than at present.

CHAPTER VIII.

CONCLUSION.

KIND OF PAVEMENT TO BE CONSTRUCTED.

A material, which may be suitable for surfacing a street in one part of a city, may not be suitable even for the foundation to a pavement in another part. Streets are not usually paved as soon as they are laid out, and seldom are they paved until the traffic is sufficient to produce a strong public sentiment favoring their improvement. Before a street is covered with what may be styled a permanent pavement, it usually passes through all stages of temporary repair. It is first graded and turnpiked. Then if it is sandy, clay is added and, if clayey, sand is added. Ditches or rough gutters are dug alongside the roadway to carry off the surface water. The next step in the process of development is the addition of gravel, which may be added in patches or perhaps spread as a layer over the entire surface. Broken stone is often used in place of gravel. These improvements serve to keep the street in fair condition part of the time, and serve to improve the condition of the road bed for the time when more permanent pavements are laid. Eventually, if the street is in the residence section, either a macadam, wooden block, brick or asphalt pavement will be constructed. Should the business section of the city eventually include this street, the pavement may need to be changed to granite block, depending, of course, upon the character of the traffic. With each step, the foundation must be strengthened and frequently

the surface of one pavement can be used for the foundation to the next.

As has been pointed out, the selection of a pavement and of the materials for that pavement must be made separately for each city, town or village and even for each street. Pavements, which are satisfactory on certain streets in one city, may be altogether undesirable in another city where the choice of a pavement is under consideration. A certain kind of pavement in two different cities, where traffic and sub-soil conditions are the same, may be satisfactory in one, and very unsatisfactory in the other,—due either to a difference in the kind of materials used or to the methods of construction. Thus, it may be said, that every street "is a law unto itself." A careful study of pavements in use is instructive and furnishes many important ideas as to the way in which materials wear under different methods of construction and under a variety of traffic and atmospheric conditions.

In general it may be said that for most of the Wisconsin cities with the exception of the larger, the macadam pavement is most desirable for residence streets, while brick, asphalt and granite block can be used to best advantage on the business streets. The streets which are to be classed as residential and business will depend upon the city considered. The method of constructing the pavement and the kind of materials used will also depend upon local conditions.

Then we must conclude, that analogies drawn between the pavements of different cities may be very misleading. Care in selecting a pavement which is adapted to the various conditions; care in securing the best materials for construction; care in constructing the pavement; and careful attention to maintenance are the essential things to be considered.

SMOOTH TRACKS.

Thus far in this report nothing has been said concerning the use of iron or steel tracks. It is known, however, that in some of the cities the truckmen can only carry the enormous loads

that they do, by using the street car tracks for the wheels to run in. Although the car tracks are the cause of many of the accidents to vehicles, they also assist very greatly in moving heavy loads over the streets. In this way they have a conservative as well as a destructive influence.

The ease with which a heavily loaded vehicle can be drawn on a steel track, has lead to the advocacy of laying steel tracks especially for this purpose. The expense which this would incur, however, makes it practically prohibitive. It is suggested, that the same object might be attained by constructing strips of smooth sheet pavement alternating with a well constructed stone block pavement. For example, the pavement might be built out of stone blocks with the exception of four strips ten inches wide, two on each side of the street car tracks. These strips, running lengthwise of the street, would be laid the same interval apart as the two rails of the car tracks. They could be constructed out of any of the materials used in smooth pavements, asphalt, cement concrete or bituminous macadam. It appears that this combination might produce a pavement which would be especially desirable wherever there is an appreciable grade. The stone blocks would furnish the desired foot hold for the horses, while the strips of cement concrete would provide a smooth, unobstructed wheel track for the vehicles.

Some difficulty might be experienced in joining the two but it is thought that this could be overcome after a little experimentation.

SIZE OF LOADS.

Everywhere there is a tendency to overload horses used for teaming in the cities. If one should stand on the crowded thoroughfare of any of the large cities in this country,—an hour would not pass without witnessing the most brutal treatment of a team by some driver who had overloaded his beasts of burden. That horses are not able to haul the loads to which they are attached, is not a result of the pavement. It is well known

that no matter what kind of pavement is constructed men will always try to haul the maximum load, and in so doing, someone is sure to overload.

The maximum load which can be hauled is controlled by the weight of load that can be hauled over the poorest pavement between the market and the place of delivery. It may happen that over three miles of the pavement a team can haul a load of 4,000 pounds while over one mile only 2,000 pounds can be pulled. This being the case, the size of the load must be limited to 2,000 pounds. *The pavements in the business part of the city should be so constructed that the force of traction will be everywhere nearly uniform.*

SYSTEM IN MAINTENANCE.

In the larger cities a permanent system of cleaning and maintenance is imperative. In the smaller cities with only a few blocks or a mile or two of pavements this is not a difficult problem. The work in these instances can be done by hiring temporary labor under the supervision of the city marshall or chairman of the street committee. However, the paved street, no matter where it is, must be kept up, if one expects to receive from it the best service. As the mileage of pavements increases, the system of maintenance must also be extended. In some of the larger cities it requires almost an army of men, constantly employed, to clean and repair the pavements. This work, in some cities, is let out on contract and in others it is performed by the city. Under both systems there is more or less corruption but experience seems to favor the latter.

The cleaning, repairing, sprinkling and superintendence of the streets should be under the control of the street committee or board of public works and in the immediate charge of a street superintendent or street commissioner. The paved portion of the city should be divided up into districts, each of which should be placed in charge of a street overseer. The length of street included in a district will depend upon the kind of pavement and the nature of the traffic. It should be the duty of the

overseer to keep the pavement and sidewalks in repair; keep the pavement, gutters, crosswalks and sidewalks clean; regulate the sprinkling; remove snow and ice when necessary; and care for the parked areas and shade trees. Necessary tools, carts and materials for repairing should be furnished by the city.

The overseer will not only be responsible to the street commissioner for the condition of the streets under his charge but his work will also be under the constant surveilance of every resident of the district. Any neglect of the street, in any particular, will usually be a subject for complaint by the citizens. Any lack of attention or negligence should be reported to the commissioner and if the street is not being cared for satisfactorily he can recommend to the Board of Public Works the removal of the overseer and the appointment of a new man. This plan will insure efficient services.

After a few years many of the men will become very proficient in their work and will take a pride in the cleanliness of the section over which they may have charge. The maintenance districts or sections, into which the city should be divided, should each include from three to four miles of macadam pavements. Gillespie says, "The labor of one man will keep in repair three miles of well made and well drained road for the first two years after its formation; and four miles for the next two years." He further says, "Supposing the road to be already in good condition, that is, in proper shape and free from holes, ruts, mud and dust; to keep it so requires two fundamental operations:

1. The continual removal of the daily wear of the materials, whether in the shape of mud or dust.

2. The employment of materials to replace those removed.

Deterioration always takes place in a geometrical ratio. The better the state in which the road is kept the less are the injuries to it and, therefore, the less the expense of keeping it in this excellent condition." (Gillespie, p. 205.)

The section overseer should be appointed by the police commissioners, or some other semi or non-political board, upon recommendation of the street commissioner and they should serve

through good behavior. They should be required to make monthly reports to the street commissioner, giving a detailed statement of the condition of the pavements, gutters and sidewalks. Every man employed as an overseer should be required to pass an examination covering the duties of his position. The street superintendent should bring the overseers together twice a month, and instruct them in matters pertaining to road construction and maintenance.

In their work, the overseers should be supplied with hand dump carts, shovels, hoes, rakes, brooms and such other utensils as may be required in the performance of their work. Wooden hoes are preferable to iron, and willow brooms are preferable to corn.

Crushed rock to be used in making repairs should be hauled onto the street and placed in convenient bins at the side of the street. It is thought that neat bins, built out of stone, brick or concrete, holding two yards of crushed stone, and having covers, would be preferable to loose piles of stone along the street. Provision should be made for such bins at the time the street is paved.

Four overseers, whose districts join should have a small house in common, in which their tools can be kept.

If the city is provided with waste paper boxes, ash cans and garbage boxes, it should be the duty of the overseer to see that these are emptied by the collectors at the proper time. He should have authority to report any neglect in these duties to the commissioner.

In the above it has not been the intention to present the details of the section system of maintenance. These should be worked out to suit the needs of each individual city. The plan can be carried out with the most gratifying success in any town, village or city in which the public affairs are administered with a reasonable degree of integrity.

DETAILS OF CONSTRUCTION.

In the construction of a block pavement on ground which requires sub-surface drainage, especially where the joints are filled with sand, it is thought that it might be advantageous to connect the sand cushion, at intervals, with the sub-surface drains. Part of the water which falls on the pavement sinks through the sand joints into the cushion where it undoubtedly remains for some time, furnishing the moisture necessary for the decomposition of the waste which is carried into the joints by the water. During periods of alternate freezing and thawing conditions of rapid drainage are very desirable. The water, which collects in the porous sand and which fills the joints and forms the cushion, may, by freezing, injure seriously some part of the pavement.

The joints ought only to be filled with sand when the foundation is sand and gravel. If sand is used to fill the joints of a block pavement having a concrete foundation, some provision should be made to drain, quickly, the sand of the cushion and joints.

The details of construction in the case of most pavements must be worked out for each individual street. The need of sub-soil drainage, the thickness of the foundation, the kind and thickness of the surface, the size of the gutters, the thickness of the curbing, the need of storm water sewers, the crown and grade of the street,—all of these can be determined rightly, only after a series of careful observations have been made on the streets to be paved.

The time to make estimates of the size of gutters and storm water sewers, is during the heavy storms or when the snow melts in the spring. Yet, some city engineers have never been out during a storm to learn by observation what is needed to take care of the rain water.

The engineer should base his opinion of the kind of material to be used in a pavement, mainly upon the traffic conditions, which he should know from personal observation, reducible

to a quantitative basis. Too many pavements are selected to satisfy some person's whim or fancy. It may be an alderman, the mayor or the city engineer,—but, in any case, we should begin to appreciate the fact, that "fancies" are expensive and seldom practical.

STATE AND COUNTY HIGHWAYS.

In another part of this report I have stated it as my opinion that the state, county, town, city and village should each have a part in the improvement of the highways. There should be a state department of highways, to which should be entrusted the construction and maintenance of state highways, and such commission should co-operate with the counties and towns in which pavements are being built.

It is thought that the counties could do a great deal to improve the highways, if they would make the "County Surveyor" also "Superintendent of Highways and Bridges." Pay him a salary of fifteen hundred or two thousand dollars and require him to be thoroughly familiar with the construction of pavements and bridges.

Each town should have a deputy surveyor, subordinate to the county surveyor, to whom the immediate supervision of the highway improvements should be entrusted.

It is time that the methods of road construction and maintenance were systematized and placed under the control of persons especially trained for this work. Today the highways, outside of the large cities, have practically no supervision and there is only a feeble attempt being made to provide permanent improvements.

THE USE OF CONVICT LABOR.

The use of convict labor in the construction of state, county and city highways commends itself very strongly to any one who has given attention to this subject. The able bodied prisoners in the state penitentary and in the county and city jails should be employed in the preparation of road metals or in the

construction of pavements. The employment of this army of men for several years ought to result in the construction of miles of excellent pavements in any state where the plan is tried. However, until provision is made for a state highway commission to which is entrusted the improvement of the highways of the state, this labor must remain employed as at present.

Each city should have a work house, equipped with a rock crusher, to provide employment for vagrants. La Crosse county, at present, employs the convicts in her jail to break stone for macadam. This practice can be followed to advantage by other counties in the state.

PAYING THE EXPENSE OF MAINTENANCE.

If the abutting property owners, in the cities, were compelled to pay two-thirds of the cost of cleaning and repairing the pavements, as well as two-thirds of the cost of construction, it is thought that there would be less difficulty in securing the installation of more permanent pavements. Under a system, however, whereby the property owners pay the initial cost of construction and the city the cost of cleaning and maintenance there is a strong tendency to compel the adoption of pavements which can be constructed cheaply but which are expensive to maintain. It is believed that more attention should be given to the cost of maintenance, when considering the suitability of various materials for paving. The question of maintenance will never, it is feared, receive the consideration due it, until the method of assessing benefits includes the estimated cost of maintenance.

In estimating the cost of a pavement one should consider the probable condition of the pavement at least twenty years hence and estimate the probable cost of the maintenance during that period. The ultimate cost of the pavement can then be estimated by adding to the probable cost of maintenance the initial cost of construction. In computing the cost of maintenance, it is necessary to calculate the weight of traffic to which the street will be subjected, in traffic weight per square yard,

and consider this in connection with the probable effect of weathering.

Having determined the cost of construction and the cost of maintenance, based on climatic conditions, nature of pavement and traffic-weight, of the various pavements, the choice of a pavement becomes a matter of balancing the desirable and undesirable features against the difference in average cost per year.

RÉSUMÉ.

An attempt has been made in this report to give all available information concerning the pavements that have been constructed in Wisconsin cities. The cost of construction has been, as a rule, easy to obtain. Very little difficulty was experienced in ascertaining the manner in which the pavements were built, as well as the kinds and sources of the materials used and the date of construction. Estimates of the cost of maintenance and cleaning, information as to the traffic conditions and estimates of the influence of weathering could be obtained only with approximate accuracy.

The records of most of the cities show only the cost of construction and the cost of miscellaneous street improvements. In very few cases have the expenses of repairing, cleaning and sprinkling been separated from one another. Where they had been kept separate very few cities were able to give the cost of these items for each street. In order, however, to know fully the value of the different pavements these items should be carefully recorded.

INDEX.

PUBLICATIONS

OF THE

Wisconsin Geological and Natural History Survey.

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1. Bulletins.

The publications of the Survey are issued as bulletins, which are numbered consecutively. Each bulletin is independently paged and indexed, no attempt being made to group them in volumes. The bulletins are issued in three series,

A. *Scientific Series.*— The bulletins so designated consist of original contributions to the geology and natural history of the state, which are of scientific interest rather than of economic importance.

B. *Economic Series.*— This series includes those bulletins whose interest is chiefly practical and economic.

C. *Educational Series.*— The bulletins of this series are primarily designed for use by teachers and in the schools.

The following bulletins have been issued:

Bulletin No. I. Economic Series No. 1.

On the Forestry Conditions of Northern Wisconsin. Filibert Roth, Special Agent, United States Department of Agriculture. 1898. Pp. VI., 78; 1 map. Sent on receipt of 10c.

Bulletin No. II. Scientific Series No. 1.

On the Instincts and Habits of the Solitary Wasps. George W. Peckham and Elizabeth G. Peckham. 1898. Pp. IV., 241; 14 plates, of which 2 are colored; 2 figures in the text. Sold at the price of $1.50 in paper and $2.00 bound.

Bulletin No. III. Scientific Series No. 2.

A Contribution to the Geology of the Pre-Cambrian Igneous Rocks of the Fox River Valley, Wisconsin. Samuel Weidman, Ph. D., Assistant Geologist Wisconsin Geological and Natural History Survey. 1898. Pp. IV., 63; 10 plates; 13 figures in the text. Out of print.

Bulletin No. IV. Economic Series No. 2.

On the Building and Ornamental Stones of Wisconsin. Ernest Robertson Buckley, Ph. D., Assistant Geologist Wisconsin Geological and Natural History Survey. 1898 (issued in 1899). Pp. XXVI., 544; 69 plates, of which 7 are colored, and 1 map; 4 figures in the text. Sent on receipt of 30c.

Bulletin No. V. Educational Series No. 1.

The Geography of the Region About Devil's Lake and the Dalles of the Wisconsin, with some notes on its surface geology. Rollin D. Salisbury, A. M., Professor of Geographic Geology, University of Chicago, and Wallace W. Atwood, B. S., Assistant in Geology, University of Chicago. 1900. Pp. X., 151; 38 plates; 47 figures in the text. Sent on receipt of 30c.

Bulletin No. VI. Economic Series No. 3. Second Edition.

Preliminary Report on the Copper-Bearing Rocks of Douglas county, and parts of Washbnrn and Bayfield Counties, Wisconsin. Ulysses Sherman Grant, Ph. D., Professor of Geology, Northwestern University. 1901. Pp. VI., 83; 13 plates. Sent on receipt of 10c.

Bulletin No. VII. Economic Series No. 4.

The Clays and Clay Industries of Wisconsin. Part I. Ernest Robertson Buckley, Ph. D., Assistant Wisconsin Geological and Natural History Survey. In charge of Economic Geology. 1901. Pp. XII., 304; 55 plates. Sent on receipt of 20c.

Bulletin No. VIII. Educational Series No. 2.

The Lakes of Southeastern Wisconsin. N. M. Fenneman, Ph. D., Professor of Geology, University of Colorado. 1902. Pp. XV., 178; 36 plates, 38 figures in the text. Sent (bound) on receipt of 50 cents.

Bulletin No. IX. Economic Series No. 5.

Preliminary Survey of the Lead and Zinc Region of Southwestern Wisconsin. Ulysses Sherman Grant, Ph. D., Professor of Geology, Northwestern University. 1903. Pp. VI or VIII, 97; 2 maps, 2 plates, 8 figures in the text. Sent on receipt of 10 cents.

Bulletin No. X. Economic Series No. 6.

Highway Construction in Wisconsin. Ernest Robertson Buckley, Ph. D., State Geologist of Missouri, formerly Geologist, Wisconsin Geological and Natural History Survey. 1903. Pp. XVI, 339; 106 plates, including 26 maps of cities. Sent on receipt of 30 cents.

2. Biennial Reports.

The Survey has published three biennial reports, which relate to administrative affairs only and contain no scientific matter.

First Biennial Report of the Commissioners of the Geological and Natural History Survey. 1899. Pp. 31.

Second Biennial Report of the Commissioners of the Geological and Natural History Survey. 1901. Pp. 44.

Third Biennial Report of the Commissioners of the Geological and Natural History Survey. 1903. Pp. 35.

4. Hydrographic Maps.

There have been prepared hydrographic maps of the principal lakes of southern and eastern Wisconsin. This work is in charge of L. S. Smith, Assistant Professor of Topographical Engineering, University of Wisconsin.

The following maps are now ready:

		Size of Plate, Inches.	Scale, Inches per mile.	Contour Interval, Feet.
No. 1.	Lake Geneva.....	17.5x10.8	2	10
No. 2.	Elkhart Lake........................	15.5x13.1	5	10
No. 3.	Lake Beulah....	22.5x20.0	6	10
No. 4.	Oconomowoc-Waukesha Lakes.....	29 8x19.1	2	10
No. 5.	The Chain of Lakes, Waupaca	21.7x20.6	6	10
No. 6.	Delavan and Lauderdale Lakes	22.5x16 8	4	10
No. 7.	Green Lake	26 0x17.8	3.2	20
No. 8.	Lake Mendota..................... ..	23.7x19.5	6	5
No. 9.	Big Cedar Lake......................	18.0x13.5	2.9	10
No. 10.	Lake Monona	17.6x17.3	4	5

In all of these maps the depth of the lakes is indicated by contour lines, and by tints in all except No. 1. They are sent on receipt of 15 cents each except Nos. 4 and 8, for which 20 cents are required. They may be had either mounted in a manilla cover, or unmounted.

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